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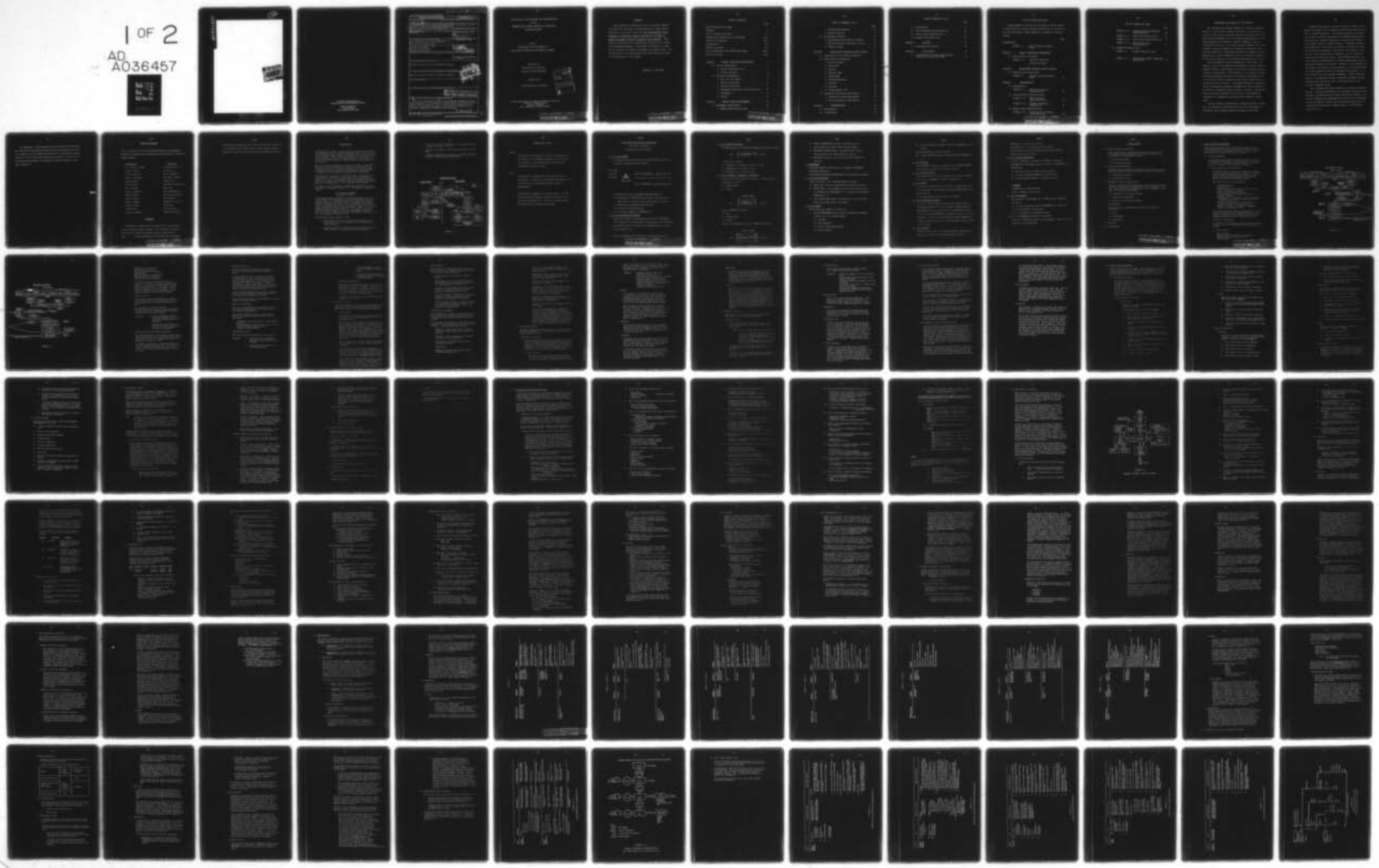

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This volume represents Part ~~VI~~ 6 of a six volume set reproducing the major work accomplished by the International Purdue Workshop on Industrial Computer Systems during the past eight years. This material is reprinted from the Minutes of the Workshop and represents some of the Work carried out by the Man/Machine Communications Committee of the Workshop.

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SIGNIFICANT ACCOMPLISHMENTS AND DOCUMENTATION OF THE INTERNATIONAL PURDUE WORKSHOP ON INDUSTRIAL COMPUTER SYSTEMS

PART VI

GUIDELINES FOR THE DESIGN OF MAN/MACHINE INTERFACES FOR PROCESS CONTROL

Prepared for

Department of the Navy

Office of Naval Research

January 1977

Distribution is Unlimited

Purdue Laboratory for Applied Industrial Control
Schools of Engineering
Purdue University
West Lafayette, Indiana 47907

FOREWORD

This material is published as part of Contract N00014-76-C-0732 with the Office of Naval Research, United States Department of the Navy, entitled, The International Purdue Workshop on Industrial Computer Systems and Its Work in Promoting Computer Control Guidelines and Standards. This contract rpovides for an indexing and editing of the results of the Workshop Meetings, particularly the Minutes, to make their contents more readily available to potential users. We are grateful to the United States Navy for their great help to this Workshop in this regard.

Theodore J. Williams

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LIST OF FIGURES AND TABLE

Figure numbers used here are the same as those assigned to these figures in their previous publication in the Minutes of the International Purdue Workshop on Industrial Computer Systems.

LIST OF FIGURES AND TABLE

BACKGROUND INFORMATION ON THE WORKSHOP

The International Purdue Workshop on Industrial Computer Systems, in its present format, came about as the result of a merger in 1973 of the Instrument Society of America (ISA) Computer Control Workshop with the former Purdue Workshop on the Standardization of Industrial Computer Languages, also co-sponsored by the ISA. This merger brought together the former workshops' separate emphases on hardware and software into a stronger emphasis on engineering methods for computer projects. Applications interest remains in the use of digital computers to aid in the operation of industrial processes of all types.

The ISA Computer Control Workshop had itself been a re-naming in 1967 of the former Users Workshop on Direct Digital Computer Control, established in 1963 under Instrument Society of America sponsorship. This Workshop in its annual meetings had been responsible for much of the early coordination work in the field of direct digital control and its application to industrial process control. The Purdue Workshop on Standardization of Industrial Computer Languages had been establsihed in 1969 on a semiannual meeting basis to satisfy a widespread desire and need expressed at that time for development of standards for languages in the industrial computer control area.

The new combined international workshop provides a forum for the exchange of experiences and for the development of guidelines and proposed standards throughout the world.

Regional meetings are held each spring in Europe, North America and Japan, with a combined international meeting each fall at Purdue University. The regional groups are divided into several technical committees to assemble implementation guidelines and standards proposals on specialized hardware and software topics of common interest. Attendees represent many industries, both users and vendors of industrial computer systems and components, universities and research institutions, with a wide range of experience in the industrial application of digital systems. Each workshop meeting features tutorial presentations on systems engineering topics by recognized leaders in the field. Results of the workshop are published in the Minutes of each meeting, in technical papers and trade magazine articles by workshop participants, or as more formal books and proposed standards. Formal standardization is accomplished through recognized standards-issuing organizations such as the ISA, trade associations, and national standards bodies.

The International Purdue Workshop on Industrial Computer Systems is jointly sponsored by the Automatic Control Systems Division, the Chemical and Petroleum Industries Division, and the Data Handling and Computations Division of the Instrument Society of America, and by the International Federation for Information Processing as Working Group 5.4 of Technical Committee TC-5.

The Workshop is affiliated with the Institute of Electrical and Electronic Engineering through the Data Acquisition and Control Committee of the Computer Society and the Industrial Control Committee of the Industrial Applications Society, as well as the International Federation of Automatic Control through its Computer Committee.

ORIGIN OF GUIDELINES

This is a reprint of the set of guidelines developed by the Man/Machine Communications Committee of the International Purdue Workshop on Industrial Computer Systems.

The Committee:	Affiliation
R. F. Carroll, Chairman	B.F.Goodrich Chem. Co.
Joseph S. Alford	Eli Lilly & Co.
Paul M. Augenstein	Taylor Instruments
Robert A. Williamson	The Foxboro Company
Renzo Dallimonti	Honeywell Inc.
Bob L. Hartway	Los Alamos Scientific Lab
Fred J. Martino	Macro Corp.
George T. Paulissen	Shell Development Co.
Daniel R. Shern	The Procter & Gamble Co.
James B. Fortier	PPG Industries
Donald G. Kempfer	Standard Oil of Ohio
Thomas M. Furlan	Inland Steel
John Zarrella	Acco Bristol Div.
Richard D. Thompson	Applied Automation Inc.

DISCLAIMER

The committee recognizes that the present form of the Guidelines raises more questions than it answers. This is because its original intention is to provide the designer only with a proper state of mind . . . . . one which prepares him for receiving useful information

rather than the information itself! Also, the term "man" is used only as a convenience term to imply operator, person, human or mankind, whenever the latter terms could have been more specifically utilized.

INTRODUCTION

The growing use of computer control systems with their large information and control data bases is focusing increasing attention on the problem of interfacing the human operator in the system with the process and the control computer. There is much that remains to be learned about the optimum coordination of men and machines, and the need to specify and design operating interfaces is a current problem in every process control project.

There is a need for a systematic approach to the design of man/machine interfaces. These guidelines are an attempt to provide an orderly thought process for the ultimate specification of an effective MMIF, or operator's console, as opposed to the details of implementation. It is intended to be both process and interface device independent.

The guideline is organized in a "top-down" format. The primary decisions relating to the overall scope of the job to be performed are examined first. Out of this top-level view, the requirements that impinge upon interface design are identified and ultimately combined with human factors engineering to create a functional specification.

To provide a frame of reference, a Man/Machine System Model is postulated which is diagrammed in Figure i.1. Two important subsystems are defined:

The personnel subsystem
The machine subsystem

The Man/Machine Interface (MMIF) is that boundary between the two subsystems across which information and control manipulation flows. In physical terms, it is typically the face of a console which contains displays and keyboards of various types. The hardware and software behind this boundary participates in translating human inputs to control signals and process inputs into data displays for humans. It will be termed the Man/Control System Translator. The boundary between this translator and the computer is called the Man/Computer Interface or MCIF. In a similar fashon, we have the Process/Computer Translator, and the Process/Computer Interface, or PCIF.

The guidelines develop an approach which:

1. Reviews the objectives of an overall system operation and helps identify a set of constraints for the process and personnel subsystems.

2. Identifies important characteristics of the operations control center relevant to the system's constrained objectives.

3. Identifies important characteristics of the human operator relevant to the control center.

4. Identifies the important functional characteristics of the MMIF.

5. Considers implementation techniques of the MMIF from consideration of these functional requirements.

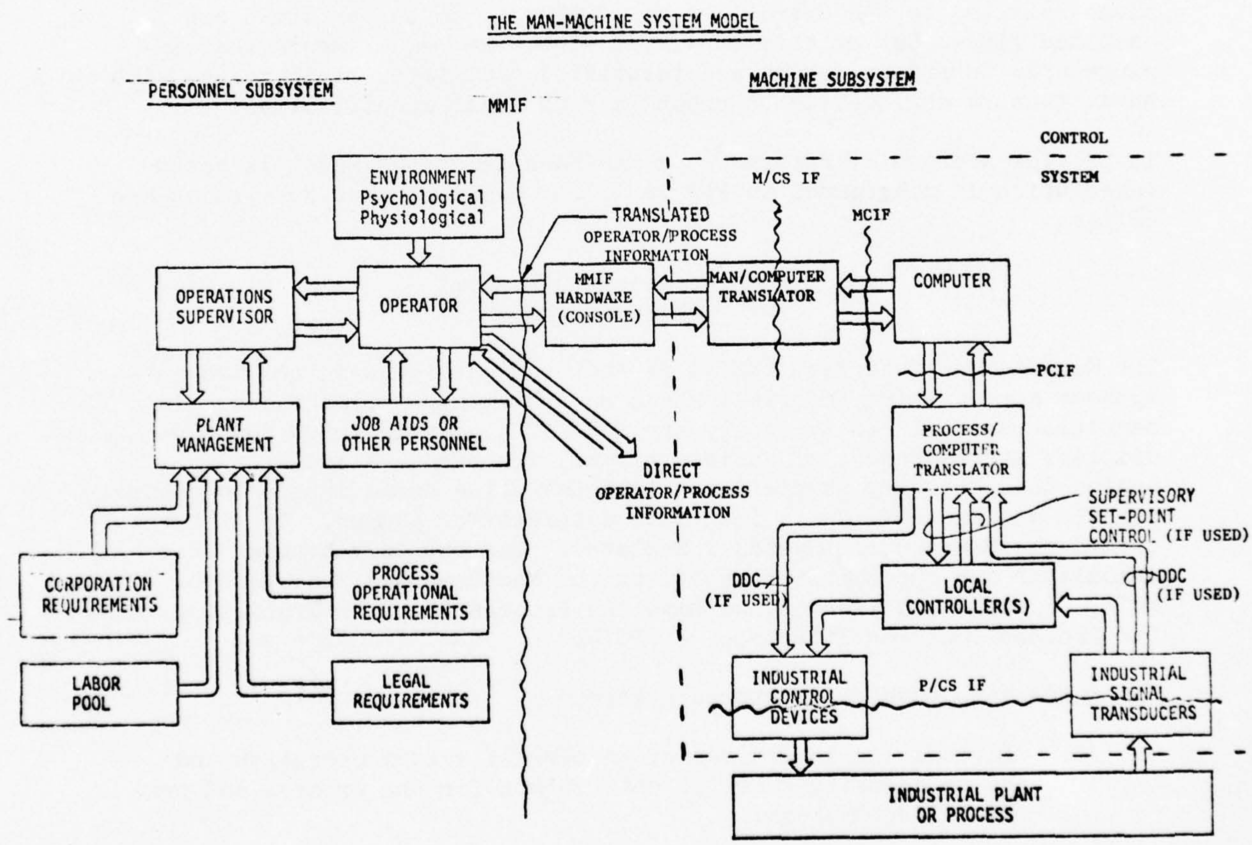


FIGURE i.1

PURPOSE AND SCOPE

Purpose:

The purpose of this document is to serve as a guideline for the definition of a computer-directed process control operator's interface. This interface will be defined as the "Man/Machine Interface", or MMIF.

Scope:

This guideline is intended to be both process and device independent. It deals with the functional requirements of the interface and the corresponding functional methods of implementation.

The guideline is organized in a "top-down format. The high level and primary decisions relating to the functions to be performed are examined first. From this, the MMIF requirements may finally be defined and specified.

HOW TO THINK ABOUT YOUR MMIF DESIGN TASK

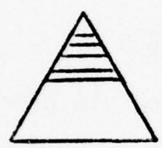
Key Points of Guideline

(Referenced by Section Number)

1. (0.0) TOP DOCUMENT

The Committee views this Guideline as the TOP DOCUMENT (hitherto unavailable) for MMIF guideline literature:

Total MMIF Guideline Literature



Purdue (TOP DOCUMENT) - Concept; Functional

Others (SUPPORTIVE) - Details; Configuration

This Guideline outlines a SYSTEMATIC THOUGHT PROCESS for:

(1) Identifying the STARTING POINT for design (which varies with application: one can enter this process wherever suitable);

(2) Establishing a CONCEPTUAL design approach;

(3) Producing a FUNCTIONAL design;

and (4) Determining a METHOD for IMPLEMENTING it.

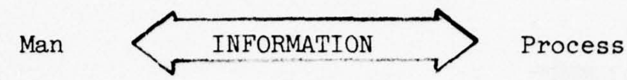
2. (0.0) PROCESS/DEVICE INDEPENDENT

Hense this Guideline is APPLICATION (process/device) INDEPENDENT. Other references (see bibliography) provide guidelines for CONFIGURING a functional design for a particular APPLICATION (spacing of keys, size of displays, etc.).

They are SUPPORTIVE of this Guideline and should be used with it.

3. (4.0) INFORMATION EXCHANGE

The MMIF implements an INFORMATION EXCHANGE between MAN AND PROCESS:



3 functions are involved:

(1) GENERATION of information from process data

(2) PRESENTATION of information to man

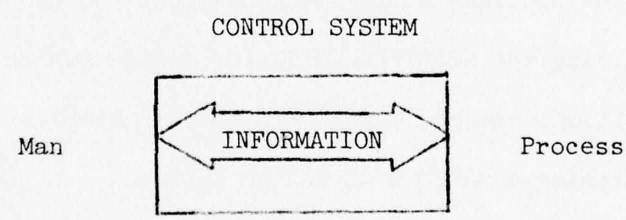
(3) MANIPULATION of information by man

4. (0.0) 2 MACHINES, 3 LANGUAGES, 3 TRANSLATORS

The term "man-machine-interface" is generic. In process control 2 MACHINES are involved:

(1) CONTROL SYSTEM

(2) PROCESS



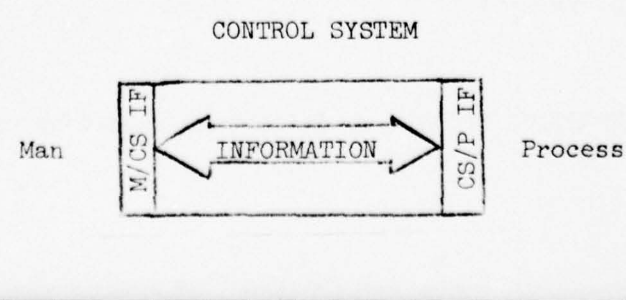
Hence, 3 LANGUAGES are present:

(1) MAN

(2) CONTROL SYSTEM

(3) PROCESS

requiring 3 TRANSLATORS, which are 3 VERSIONS of the MMIF:



(1) CONTROL SYSTEM/PROCESS Interface - translates process - sensed signals into Control System internal signals;

(2) MAN/CONTROL SYSTEM Interface - translates Control System internal signals into human displays and controls;

(3) MAN/PROCESS Interface - entire control system considered as translator.

* 5. TRANSPARENCY

* OVERRIDING OBJECTIVE of MMIF design is a completely TRANSPARENT MAN/PROCESS TRANSLATION.

* AVOID IMPOSING TRANSLATOR CHARACTERISTICS on the information exchange.

6. (0.0) TOP-DOWN APPROACH

Achieve this objective by a TOP-DOWN approach to design:

(1) NEEDS FIRST - define the problem before choosing the solution;

(2) CONCEPT FIRST - a well-thought-out concept begets details which are CONSISTENT and COMPLIMENTARY to it; changes are EVOLUTIONARY EXTENSIONS of it;

(3) AVOID "UPSIDE-DOWN" design - the inverse of (1) and (2) wherein details and changes define a new concept.

7. (3.0) 4 PHASES

This approach has 4 PHASES (see Figure 3.1):

I Identify REQUIREMENTS (social, legal, environmental, management policies, etc.) of 4 elements of MMIF:

(1) Personnel

(2) Plant management

(3) Control system instrumentation

(4) Process behavior;

II Allocate FUNCTIONS among MAN (personnel) and MACHINE (control system);

III Analyze TASKS to perform functions;

IV Produce FUNCTIONAL design; determine method of IMPLEMENTING it.

7. (1.0) PERSONNEL

PLANT MANAGEMENT objectives increasingly affect CONTROL STRATEGY and the number, type and role of PEOPLE involved.

8. (1.0) UNPREDICTICALITY

UNPREDICTABLE aspects of process behavior are often best handled through man's JUDGEMENTAL and adaptive capabilities.

9. (1.0) PACING

Does man PACE process (and control system), or vice-versa? BOTH can be applicable - MAN PACES during startup; MACHINE PACES during normal running.

Can man ANTICIPATE process behavior or only REACT?

10. (2.2) ENVIRONMENTAL PARADOX

The MMIF is usually physically bounded by the CONTROL ROOM; its ENVIRONMENTAL ASPECTS are a MAJOR VARIABLE in MMIF performance. PARADOXICALLY, man and control-system both CONTRIBUTE TO (noise, etc.) and must be ACCOMMODATED BY (temperature controls, etc.) this environment. Control room ARCHITECTURE and VISUAL APPEARANCE are extremely important factors; it is NOT SUFFICIENT to place the MMIF in ANY OLD ROOM.

11. (3.0) WEDDINGS

SUCCESSFUL MMIF design are successful WEDDINGS of human factors engineering (HFE) and control system engineering (CSE).

HFE WEDS man to machine and vice-versa.

CSE WEDS process to instrumentation and vice-versa.

MMIF functional and physical design expresses TASK ALLOCATION between man and control system.

12. (4.0) TASK/TECHNIQUE/DEVICE

3 STEPS in a METHOD of determining the APPROACH to physically IMPLEMENTING the FUNCTIONAL design for information PRESENTATION and MANIPULATION:

(1) Specify the TASK (for example display setpoint);

(2) Determine ALTERNATE TECHNIQUES to accomplish task;

(3) Identify ALTERNATE DEVICES to implement technique.

* REMEMBER:

* ALTERNATES are ALWAYS AVAILABLE.

* there is NEVER only ONE solution.

13. (6.0) FULFILLMENT

This Guideline's TOP DOCUMENT role is FULFILLED after completing Section 4.0:

(1) All man- and machine-dependent REQUIREMENTS are identified;

(2) A design CONCEPT is established;

(3) It is expressed in a FUNCTIONAL design;

and (4) An IMPLEMENTATION APPROACH is established.

Now refer to SUPPORTIVE sources (see bibliography). DETAIL the implementation to your APPLICATION.

OUTLINE OVERVIEW

1.0 Overall Operation Requirements

Process and Personnel requirements are reviewed to determine all of the aspects that will specify or restrict the objective to be accomplished by the man/machine interface.

1.1 Process Requirements

1.2 Personnel Requirements

2.0 Control Center Requirements

Management and Environmental requirements that may lead to requirements and restrictions on the Control Center itself are enumerated.

2.1 Management Requirements

2.2 Environmental Factors

3.0 Man/Machine Interface Design Factors

A series of questions and statements are listed, which when answered, provides a restricted set of requirements for the man/machine interface. The questions and statements cover process, management, human factors and functional requirements.

3.1 Organization of the Design Approach

3.2 Human Factors Engineering

3.3 Translator Functional Requirements

4.0 Implementation

Various methods of implementing the man/machine interface are discussed.

4.1 Scope

4.2 Presentation

4.3 Manipulation

5.0 Glossary

6.0 Bibliography

1.0 OVERALL OPERATIONS REQUIREMENTS

Overall system operations are first examined to determine those requirements which will define or restrict the objectives which are to be accomplished by the Man/Machine Interface. This procedure is exemplified by the Guideline Flow chart of Figure 1.0.

1.1 Process Requirements

The first step in the design of an MMIF should be to collect as much pertinent information as possible about the process to be controlled. Considering the items mentioned in this section will be useful in collecting this information.

-1 Process Stability and Predictability

The primary reason for including a human in the system is to handle unpredictable aspects of the process. This is closely related to stability since unstable processes (such as those containing exothemic reactions) will amplify the effects of unpredictable events.

Some typical sources of uncertainty are:

Equipment malfunction
Utility failure
Variability of raw materials, utilities, weather
Process disturbances or upsets
Lack of complete process knowledge
Sudden poisoning of a catalyst (as opposed to gradual degradation)
Accommodation of the process for unusual situations in equipment availability, energy availability, polution control, etc.
Sensing of system behavior or characteristics for which no automatic sensors are provided
Variables not subject to automatic measurement
"Special" or "unrehearsed" runs

On the other hand some sources of variability are readily predictable and may not need human intervention to compensate. Typical of these are gradual fouling of heat exchanges and gradual changes in catalyst activity.

- Variables To Be Measured

All variables to be measured should be listed and described in detail. For most variables the description should include:

- Normal Variables

Type of sensor
Response time and consistency of response
Need for trend and historical data
System inertia

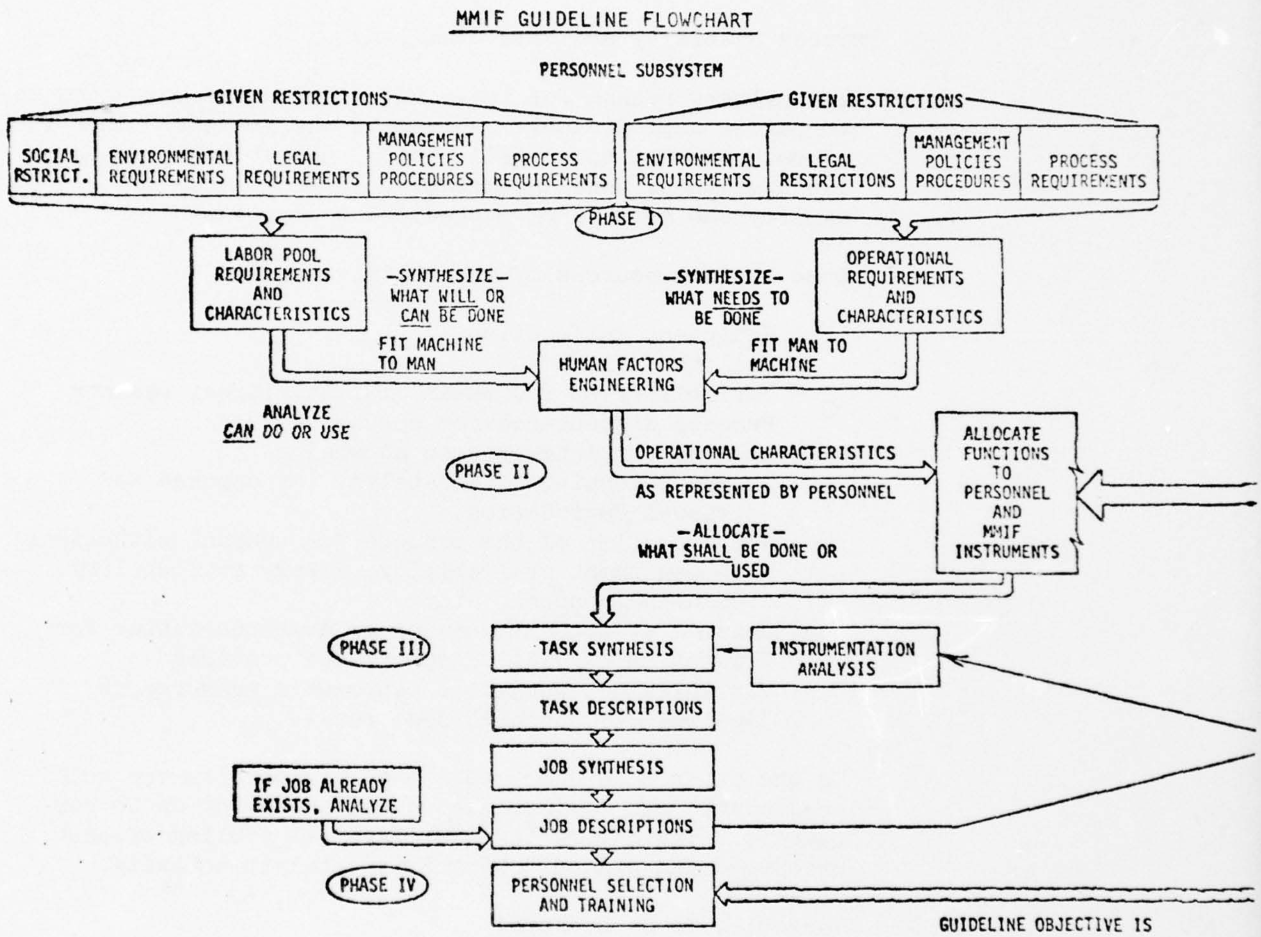

MMIF GUIDELINE FLOWCHART
PERSONNEL SUBSYSTEM
GIVEN RESTRICTIONS
SOCIAL RSTRICT.
ENVIRONMENTAL REQUIREMENTS
LEGAL REQUIREMENTS
MANAGEMENT POLICIES PROCEDURES
PROCESS REQUIREMENTS
GIVEN RESTRICTIONS
ENVIRONMENTAL REQUIREMENTS
LEGAL RESTRICTIONS
MANAGEMENT POLICIES PROCEDURES
PROCESS REQUIREMENTS
PHASE I
LABOR POOL REQUIREMENTS AND CHARACTERISTICS
-SYNTHESIZE- WHAT WILL OR CAN BE DONE
-SYNTHESIZE- WHAT NEEDS TO BE DONE
OPERATIONAL REQUIREMENTS AND CHARACTERISTICS
FIT MACHINE TO MAN
HUMAN FACTORS ENGINEERING
FIT MAN TO MACHINE
ANALYZE CAN DO OR USE
PHASE II
OPERATIONAL CHARACTERISTICS
AS REPRESENTED BY PERSONNEL
ALLOCATE FUNCTIONS TO PERSONNEL AND MMIF INSTRUMENTS
-ALLOCATE- WHAT SHALL BE DONE OR USED
PHASE III
TASK SYNTHESIS
INSTRUMENTATION ANALYSIS
TASK DESCRIPTIONS
JOB SYNTHESIS
IF JOB ALREADY EXISTS, ANALYZE
JOB DESCRIPTIONS
PHASE IV
PERSONNEL SELECTION AND TRAINING
GUIDELINE OBJECTIVE IS

FIGURE 1.0

MMIF GUIDELINE FLOWCHART

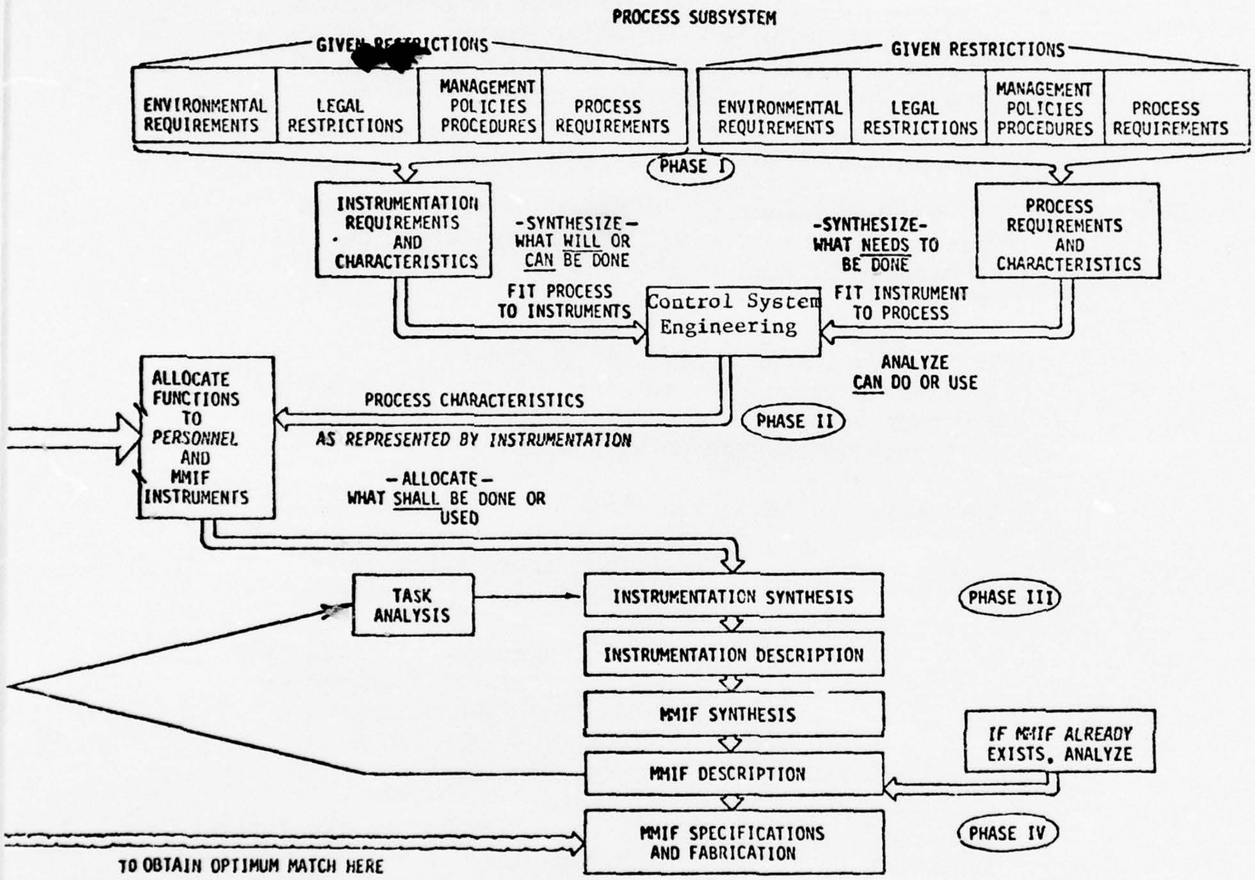


FIGURE 1.0

Expected noise and/or error
Desired engineering units
Variables derived by calculation
Expected range
Alarm settings and required action
Range and source of set points
Possible overides of constraints

In addition, variables which are difficult to measure often require very special interface considerations. For example, a variable which requires a manual laboratory type analysis needs a defined means of entering data into the system. On some important variables it may be worthwhile to check them by correlating them with other variables.

- Mode of Operation

A process may operate continuously or in a batch mode. There is often a choice between the two which is closely related to the control needs and to the MMIF.

Is it a series or a parallel process?
Does the process have a number of parallel branches?
How many steps are in series and what is available or required to surge between steps?

(examples)

a. The above questions can have an important bearing on the distribution of multiple control interfaces.

b. Required surge may sometimes be reduced by careful consideration of interface requirements.

- Outside Constraints and Legal Requirements

The constraints placed on the process or on the interface must be defined. These include policies, regulations, practices, or other restrictions imposed by management, government or unions.

For example, management or sometimes government may require storage of historical data. Union rules may restrict permissible operator duties and working hours. Any of them may impose constraints relating to safety.

- Operating Objectives

  The overall objective of the process should be carefully defined and related to the operator's duties.

  The most common objective is to produce a product at maximum profit. For this purpose the operator's scope of authority must be defined and used in determining what information is to be available and what range of control is permissible. In many situations the operator has a free reign on variables which effect product quality but is constrained at points limited by safety considerations.

  A quite different objective is in scientific experimentation. Here providing flexibility is often the most important consideration at the MMIF.

  Other possible objectives to be considered are training, safety, and pollution control.

- Measures of Performance

  What are the measurements of performance of the process, and what information does the operator need from them for optimization?

  Consideration should be given to unusual measurements, often relating to product quality and which may require:

  -Information from remote lab or locally conducted lab tests.
  -Human judgement of product taste, smell, or other directly observable characteristics.
  -Customer or user feedback.

- Environmental Effects

  What effect does Meteorology have on the process?

  (examples) a. Temperature of a cooling-water system may change optimum control strategy.

  b. Air humidity is important in a drying application.

c. A sudden rainstorm can cause severe disturbances in some processes.

d. A violent storm can cause loss of information remoted via telephone or microwave links.

- Physical Size and Layout

The physical size and layout of the process are very important to the MMIF requirements. A process which has everything written the operators need or view will have substantially different communication and interface requirements than one which is spread over a larger or otherwise non-viewable area.

Provisions should also be made for possible future expansion of the plant.

1.1.2 Process Controls

The desired control of a process is directly dependent on the proper operation of the hardware and software used to gather and display the process parameters of interest.

- Process Control

The objective of each control loop should be studied and related to the plant objectives and to the operator's duties.

Where complex control algorithms and strategies are used, thought must be given to the degree of understanding needed by the operator. Is it necessary to understand the process, the strategy, or just the MMIF? In some cases it may be beneficial to display complex control schemes schematically for the operator, the supervisor or the engineer. Complex schemes include such things as adaptive or multivariable control or a change of algorithm depending upon conditions.

With a display it is feasible to spell out emergency recovery procedures. The value of this should be considered.

It is important to consider the consequences of control system failure in terms of important process variables, unit and plant integrity, and personnel safety. Provisions for fail-safe operation, manual or automatic backup, or redundancy must be studied.

Plant startup and shutdown imposes special requirements on the control system. Planned frequency of shutdown influences MMIF design. There may be economic or safety justification for some automatic sequencing of startup and shutdown operations.

- Special Functions

Various aspects of system performance pertaining to the control system can typically be tested and monitored on-line. These might include:

Proper operation of analog and/or digital filters.

Inactivating a loop on line in order to calibrate sensors (e.g. gas analyzers, amplifiers in the signal-computer interface, etc.)

Deliberate load or setpoint-pulsing of system, on line, to optimize controller settings, obtain loop frequency responses, etc.

Deliberate changing (or sweeping) of controlled variables to obtain wide-ranging data base needed for model generation or updating.

On line frequency analysis of data for purposes of evolving inputs to control schemes. Post mortem analysis and reporting to and in the analysis of a system failure.

- Variables to be Displayed

The consideration of the above functioning of process controls then logically leads to the variables of the process that should be displayed and manipulated.

All variables to be measured and associated with the operation of controls should be listed and described in detail. These variables might include:

Operator's feedback indications of hardware controller setpoint, gain, reset, and/or rate settings.

Indication of above parameters (and addresses for digital control algorithms.)

Valve position indication (control valves, scanning valves, etc.)

Relay status.

Hardware controller status (Computer-mode, local-mode, bypassed, etc.)

Computer-Process hardware interface status (e.g. is process interface generating pulses, shorted out, etc.)

Hardware-controller utility status (instrument air pressure, power supply voltages, steam pressure and/or temperature).

Electrical continuity of all hardware status alarm lights. (Lamp Test)

Descriptions of the variables should include consideration of response time, type of sensor, expected range, alarm settings and required action, range and source of setpoints, and possible overrides of constraints.

Some control schemes have special legal requirements (e.g. supervisory setpoint-control override during emergencies).

Schematics of the control loops may be desired for display.

Data that is displayed should indicate the validity of the measurement. The display should indicate in some manner if the variable exceeds the sensor limits (a truly bad signal). If the measurement for some reason is not being scanned, the variables should be so indicated. In any event, some indication of the measurement scanning speed (or starting and stopping point) should be available on the display).

1.2 Personnel Requirements

The overall operations review will impose certain "top-down" personnel requirements. The following section will go into detail about their needs.

-1 Who uses the console?

There are many facets to be considered in this section. It is not enough to merely say the operators are going to control the process from this console. (For purposes of discussion in this section, anyone who uses the MMIF is considered to be the "operator", although in reality he could be any of the following types of personnel.)

- Process Operator

The console operator or operators must use this console as their communication with the process. The unit must be designed to comfortably fit the user/or

users. Don't skimp - if more than one operator will spend considerable time at the console, dual entry and displays should be considered. The tasks to be performed should be enumerated.

(examples)
- -changing controller set points
- -activating control loops
- -increasing or decreasing plant throughput
- -putting computer on or off control
- -updating computer with lab results
- -changing recipe amounts when permitted
- -running equipment or process tests or diagnostic routines
- -changing console operating mode

- Engineer

Is an engineer, or a foreman, or other persons in charge of the operators? Are there operational changes to be entered into the system that are not the responsibility of the operator? Are there restrictions or operational goals imposed on the system? Will the foreman be making these changes?

What percentage of the time will this console be used for work of this type? This will vary from industry to industry. Thought should be given as to where this type of input should be accomplished. Should a particular panel or section be reserved for this use? Should this function be removed to a separate location, or simply locked-out by special keys or command-codes?

- Supervisor

Does the plant supervisor have a need for obtaining special data or data arranged in a particular way that would be used for Management decisions. Where and how often will this function be required? Will a lock-out be required?

- Programmer

After system is installed, where, how, and how much programmer activity is expected? If there is a need that is large, then the problem of how to accomplish this is very important. Should the function be combined with the engineering tasks?

If the need is small, how will it be accomplished? Will the regular console functions handle this load? Will the computer console be used? Is there a computer terminal? Will the computer need to be shut down for changes (foreground only vs. foreground-background)?

- Maintenance

  Are there provisions in your design to accomplish control system and computer maintenance? What effect does preventative maintenance (PM) have on the system? Can PM be performed on line? Is PM necessary? If not, then when repairs are made, how do the diagnostics get into the system? What about storage media, ease of use, etc.

- Training

  What effect will the training of personnel have upon the console design? What provisions for training are to be made? Is the console simplistic enough? Has Human Factors Engineering (HFE) been used properly? Can a regular operator be trained easily? Does the system make the operator feel he has a new tool or an operational aid? Is the communication between operator and the processor adequately described and instructions easily understood? Are the operators old or new to this task? Has the training taken into account that operators generally resist change?

1.2.2 Modes of Operation

What kinds of operational modes are to be performed. This, again, impacts on the console design.

- Normal Operation

  Can you define how the system is to run in the normal operating mode? Does this include startup and shutdown?

  What does the "normal" type operation mean?

  - Operate in supervisor fashion with setpoint changing (closed loop supervisory).
  - Operate in DDC mode with appropriate back-ups (closed loop).
  - Operate in monitor-type mode with instructions to operators (open loop control).

  If startup is to be performed - how will this be accomplished? Supervisory and/or open loop directed?

  Shutdown - is this a normal function or emergency? How will it be accomplished? Supervisory and/or open loop directed?

- Background Mode

  Is the system, during normal operation, capable of performing tasks other than control?

  (examples)
  - Compiling programs for real time control use.
  - Compiling and executing scientific type programs (Fortran).
  - Performing laboratory analyses or lab calculations.
  - Simulation of the plant in a faster-than-actual-time frame.
  - Analysis and debugging of operating programs and computer operating system during operation.

- Emergency Mode

  What is to be performed during emergencies? Tasks should be outlined as well as how they will be accomplished. Make a task list for control actions. Does this include emergency maintenance of system?

- Maintenance

  Have provisions been made to accomplish as much maintenance as possible while on-line (effecting production)? See "security and safety" for plant operation while off-line.

- Operational Goals

  In any of the above categories does the operator have the requirement to set the operational goals, or is this function restricted? If the operator does set the goals, does he also have the option to commit available resources to accomplish this task (i.e. can he change the plant from one level to another and appropriate the feedstock, utilities, equipment and manpower required)? If the operator is restricted, does he have ready access to the people who can set goals? Especially during emergencies?

- Off-Line Operation

  Is there to be a requirement for the computer to perform off-line (while the production unit is down)? If background tasking is not available, then off-line operation could include recompiling or assembling changes to be made in the system. If the process unit operates for short periods of time, with time available between production runs, some sort of EDP functions could be accomplished during these short breaks.

1.2.3 Security and Safety

Is the system protected from casual or accidental-type of button pushing? Does the system have a watchdog timer or similar protection against program-looping or getting lost? Does the watchdog timer protect against automatic restart as in a power failure when you don't want it to restart automatically (maybe because its been down too long)?

Are the system-programs protected (either by software or hardware) while in operation? Is the system protected with backup software which is stored in a safe place? Is the hardware special or can it be replaced easily in case of an accident? Sometimes it's worth going with a standard model to lessen the accidental-loss risk.

Can the necessary safety or recovery actions be performed from the console with the required speed?

Is the control room designed to minimize traffic and let only the authorized personnel access to the computer? Is there a visitor's viewing gallery "requirement"?

Are there to be keylocks on the console or other types of security (such as code names) for separation of duties? How are these "priviledge codes" to be controlled and monitored?

Are there security overides when necessary? An example might be during startup when normal or built-in constraints must be overridden.

1.2.4 Management Objectives and Restrictions

Here the definitions from management must be reviewed and their impact on the console evaluated, not only the number of persons to be involved in the control center operation, but any other requirements by management or the government. There are other restrictions that may be imposed - Is the job to be performed standing-up or sitting-down? Management may decide the console should be a certain length, height, color or configuration. Are there other jobs or tasks to be performed besides the main task performed at the console (in other words, off-line duties)?

Here also the definition of how the plant is to be run is determined. It may be general (i.e. certain cases run in production-limited mode, otherwise run in raw-material-efficiency mode) or it may be very specific (i.e. maintain certain conditions regardless of productivity demands

or raw materials being used). Other examples might be: If a batch plant operation, the product quality between batches must remain within certain limits. If a continuous plant, the product may vary depending on the demand or customer (i.e. crude-distillation tower operation to give more gasoline or more heating oils). Certain management restrictions also imply a special type of record be kept. This could impact the console requirements, and certainly impacts on operations personnel requirements.

1.2.5 Government

Government also impacts the console objectives. This may be very dependent on the industry. OSHA or EPA may require certain objectives be met and records kept for a number of years. Legal requirements could also be a cause for some console considerations. There are very specific requirements placed upon control rooms for Nuclear Power Plants by the Nuclear Regulatory Agency, for example.

1.2.6 Pacing

Man or machine - which paces the other? Here again, this appears to be an industry dependent variable, but this should not be over-looked. (For more on pacing, see 3.2.9 re "Psycological Fit")

Do not forget that for certain times the nature of pacing may switch. As an example, during startup and shutdown the man may pace the machine, but during normal production the machine may pace the man. The exact reverse situation can also occur! Other examples - during batch operation the machine may pace the man until an unusual occurence - then control will defer to the man. In a continuous-furnace control operation the machine will pace the man until restrictions of some variables make the automatic solution unattainable. Then the alarm alerts for the man to take over, and the man would then be pacing the machine.

2.0 Control Center Requirements

In the previous section we examined how the Man/Machine Interface might be influenced by the higher level requirements of overall process and system objectives. Now we picture the control center itself and identify factors which are relevant to it directly.

2.1 Management Requirements

This section will enumerate some of the types of company policies, industry standards, licensing regulations, major equipment contractor's requirements, and management goals and decisions that may lead to restrictions and requirements on the MMIF itself. (The guideline user must keep in mind that the following examples were chosen only as a random collection of typical requirements. As these examples jog the user's mind, he should write down his corresponding or related actual requirements.)

-1 MMIF Hardware Restrictions

-Specifications

What are the hardware restrictions that affect the design of the MMIF?

Some examples of such restrictions MIGHT be:

a) *The console will be painted company colors;*

b) The console will consist of equipment made by union companies in the U.S.A.;

c) The MMIF will withstand the factory environment;

d) Provide for the following planned future improvements........;

e) Provide for the following operational modes on a single console: normal, emergency, shutdown, startup, maintenance;

f) Provide for in-house maintenance instead of an outside vendor;

g) Make the MMIF a showplace for public relations and tours;

h) Provide for computer system backup;

i) Provide for manual overides;

j) Make this MMIF hardware and software compatible with our other interfaces;

k) Use commercially available equipment instead of in-house design and fabrication;

l) This equipment must last the life of the project, which is "X" years;

m) There must be a graphic representation of the process on or near the MMIF;

n) The MMIF must have less than 0.5% downtime;

o) Keep the overall cost less than "X" dollars.

- Legal

What are the legal requirements that apply to the MMIF? Some examples <u>MIGHT</u> be:

a) Safety, such as no sharp edges, and providing hi-voltage or other warning signs where appropriate;

b) Health, such as no toxic fumes or high noise levels;

c) May have to provide for on-the-job training;

d) Licensing or leasing may require nameplates or other items of inventory and packaging control.

e) Production reports or other logs may be a legal necessity.

-2 Operator Restrictions

- Selection

What are the operator restrictions as they relate to the type of operator that will use the MMIF? Some examples of operator restrictions <u>MIGHT</u> be:

a) This operator must be a union employee;

b) This operator will be a company man;

c) This operator will be a new hire;

d) This operator will be an in-house person;

e) This position will be relatively stable;

f) This position will be used as a training tool for personnel being promoted from a lower position to a higher position;

g) This operator must pass certain tests;

h) This operator must pass a security check.

i) This operator must posses normal (color vision, hearing, and manual dexterity.

- Responsibility

What are the management restrictions that apply to the Operator's Responsibilities and authority?

Some examples of these restrictions MIGHT be:

a) The number of operators at the console;

b) The amount of relief time for the operator;

c) Secondary duties that are required, such as maintenance or clean-up;

d) How much authority the operator has, how much of the available resources the operator is permitted to commit, or use;

e) How much responsibility the operator has;

f) How the operator's performance is to be measured.

- Legal

What are the legal requirements that apply to the operator? Some examples MIGHT be:

a) Operator may be young or old;

b) Operator may be male or female;

c) Operator may require relief time or scheduled breaks.

- Monitoring and Pacing

Does management require the machine to monitor the operator, or the operator to monitor the machine, or somewhere in between? Is the machine to pace the operator, or is the operator to pace the machine? Some examples of the various modes of operation are as follows:

a) The machine makes the decision and completes the action, then notifies the operator;

b) The machine makes the decision, notifies the operator, then completes the action - this allows the operator to manually override the action;

c) The machine suggests an action, then waits for an operator reply which could be: 1) no reply within a time period means O.K., 2) no reply means not O.K. and machine trys something else, or waits.

d) The machine alerts the operator to a problem and waits for a decision.

2.1.3 Records and Logs

Hisorical records and logs as required by management. Some examples of these are:

a) Production summaries by shift, day, week, month, etc.;

b) Shift or crew comparisons;

c) Equipment downtime and reasons;

d) Trending Charts;

e) Set point changes log;

f) Plotting capabilities;

g) MMIF downtime and repair log;

h) Alarm logs;

i) Records of operational variations, equipment by-passing.

j) Operator's Communications records (like in-flight recorders for example)

k) "Instant Playback" capability as used to "trace" sequence of events that caused a failure or accident. (casualty information)

2.2 Environmental Factors

Environmental factors may <u>enhance</u> or <u>degrade</u> the performance of the Man/Machine Interface. Use of environmental factors to enhance performance is part of the designer's objective. This section is divided into three areas of focus: man-centered, machine-centered, and physical layout.

Man-centered environmental factors are those factors which effect the operators themselves as the designer looks at the interface, ie, those environmental factors which effect or restrict the human factors engineering design.

Machine-centered environmental factors are those factors within the immediate area of the interface which affect the hardware design and implementation.

Note: The above two catagories of environmental conditions or factors are not necessarily the same. Each does not include all of the same elements. A good example of this is noise. Noisy environments will often degrade man's performance but will not likely effect the components of the control console in the same way, if at all.

Physical layout requirements form a seperate catagory of environment. It includes both man and machine factors, often simultaneously. Physical layout may often be used to compensate in part for an otherwise poor environment around the MMIF

-1 Man-Centered Environmental Factors

As the designer enumerates and evaluates the environmental factors effecting man he should keep in mind that man perceives his environment entirely through his five senses, but that his reaction to these input signals can be quite complex. Sociological factors, for example, are quite complex reactions to sensory inputs. The man-model referred to later in this outline can be useful in evaluating the importance of the various environmental factors as they effect man's physical ability, endurance, mental ability, fatigue, etc.. The environmental factors listed below have been divided into categories according to their usual effects on man. The categories are somewhat arbitrary and overlaping but serve the purpose of highlighting important effects.

- Effects on Sensory Preceptions.

a. Temperature/humidity/ventilation. The range and variations of these factors effects, among other things, man's comfort and endurance.

b. Sound. This factor can have both positive and negative effects. Such factors as frequency, intensity, duration, variation, composition, etc. are important.

c. Vibration. This factor is similar to sound but may have added effects on sense of feeling. Vibration rarely enhances environment for MMIF.

d. Light. Factors such as color, shade intensity, duration, and variation should be considered. Illumination and glare can effect ability to read for example. Poor choices of color can be emotionally irritating under some conditions. Properly used lighting effects can significantly enhance the MMIF environment.

e. Texture and geometry. These factors may often be used to enhance environment and the accuracy of man's output. Examples of this factor used to advantage are the use of different sizes and colors of panels for different functional partitions of MMIF.

f. Dust and other nontoxic contamination. These factors may reduce comfort and endurance.

- Effects on Mental and Psychological Behavior

a. Data rate input to man. Man may not be able to use information if he receives too much too rapidly.

b. Variety of input form and type. Data of similar type should be presented to man in the same way. Variety of method of presentation may be used to advantage as, for example, critical variables presented continuously on dedicated indicators.

c. Consistancy and organization. These are really human factors engineering subjects. However, some inconsistancies and disorganization may be dictated by plant or control room restrictions in which case they become environmental disadvantages.

d. Effects on "arousal level". See human factors section and the "man-model". This is an important effect but it must be used carefully. Such things as alarm bells or flashing lights are often used. Man's response often is a shift of "arousal level" and can result in erroneous action. For example, if there are too many alarms, an operator will learn to ignore them and may miss seeing an important one.

e. Fatigue and stress. Are there factors which generate stress and fatigue, which can degrade man's performance?

f. Comfort factors. Are there comfort factors or can some be added which may compensate for stress? Can the operator stand up, sit down or move about? Is the physical working space large enough, and is the room environment adequate?

- Factors With Physical Limitations

a. Amount and rate of output required of man. Can the operator do the assigned job at the rate pre-scribed and yet maintain the necessary reserve energy for possible contingency situations?

b. Toxicity/health hazards.

c. Nuclear radiation.

2.2.2 Machine-Centered Environmental Factors

- Temperature and humidity range and level (if the machine's requirements exceed the man's requirements).

- Vibration, seismic requirements

- Electromagnetic radiation. Ultra-violet, X-ray, radio-frequency, etc. (A two-way radio near a computer can disrupt its operation.)

- Electrical noise (Any sporadic electrical load on the same supply circuit as a computer will likely disrupt its operation.)

- Dust and other contamination (in refineries and chemical plants, H_2S usually effects electronics components at levels lower than man's tolerance).

- Nuclear radiation

- Variety of input forms from plant or man.

2.2.3 Physical Layout

- Predetermined factors from overall operation requirements.

- Visual observation of the process. Required or not?

- Explosion proofing.

- Safety

- Consistency. If there are several operators or operating stations, can similar jobs be done in similar ways with similar equipment?

- Other working conditions. Wiring on floor, obstacles, conveniences, etc.

3.0 Man/Machine Interface Design Factors

In the previous sections of the guidelines, emphasis has been on establishing the performance goals that the Man/Machine Interface should support and under what contraints of policy, manpower, control strategy, and physical environment the Personnel Subsystem of Fig. i.1 must exist.

We are now ready to proceed to the next step in interface design. First the restrictions and requirements generated in Guideline Sections 1.0 and 2.0 above should be reviewed and organized. Then with human factors engineering and hardware characteristics considerations, the actual interface can be defined.

3.1 Organization of the Design Approach

A thorough preparation for design requires the organization of a considerable number of factors. Some appreciation of the problem may be grasped by a reference to Figure 1.0, which showed a comprehensive flow chart for the design process.

We are now on the threshold of Human Factors Engineering and Control System Engineering. (Again, refer to Figure 1.0)

- Questions that should have been asked and answered by now[

In order to fully utilize the following information in this section of the Guideline, you must have a well-defined purpose in mind. If you have answered all of the following questions, you will have a restricted set of requirements for the MMIF. If you have not considered the following questions, but wish to continue thru this section, you are assummed to have adopted some preconceived notion about MMIF design, and the Guideline will be of much less use to you.

1. Will you utilize existing manpower or select/train according to design requirements?

2. What is the prime motivation for involving a manned control console? (Typical sections of HFE needed)

   - Research or pilot plant (all)
   - Unpredictable process (feedback & trending & auto alarming heirarchy)
   - Incomplete automation (feedback)
   - Poor reliability in hardware/software (feedback)
   - Lack of confidence in automation ("consistent MMIF" & feedback)
   - Traditional (stereotyping)
   - Safety requirements (accuracy, error recovery, transparency)
   - Maximize performance of system (all)

3. What is the available manpower pool?

- Open market
- Regional market (selection & training)
- Internal recycling
- Contractual

4. What are the physiological restrictions for operators?

- Need all physical abilities
- Need only specified abilities
  (can accommodate Handicapped)

5. What are the psychological restrictions for operators?

- Personality types
  - aggressive, dynamic, imaginative, non-conformist
  - conservative, obedient, conformist
- Intellectual types
  - semi-literate
  - decision makers, thinkers, innovators
  - consistent and reliable
  - meticulous and logical
- Social types (personality)
  - gregarious
  - loners

6. What work patterns will be required?

- Man pace machine or machine pace man
- Standard daytime hours/work schedule
- Shift hours, regular schedule
- Highly intermittent, on demand

7. What type of manpower is involved in use of console?

- Control engineer
- Programmer
- Maintenance
- Shift or routine operators
- Clerical workers
- Managers
- Supervisors
- Design analysts
- Casuals (part-time)

8. What are the rules/requirements of access to console?

- Restricted by authority
- Restricted by schedule
- Restricted by time-sharing cycling

9. Are back-up personnel needed for any types?

   - Emergency or routine occasions
   - Redundant/dedicated or temporary stand-in

10. What are motivations of operating personnel?

   - Monetary (hourly, salary, or profit sharing)
   - Self-driven curiosity (researcher, designer)
   - To meet minimum specified performance requirements according to some historical precedent (union)

11. Are job enrichment/enhancement methods to be utilized?

   - Industrial relations
   - Industrial psychology

12. What is the involvement of operating personnel?

   - Involved in operations, as scheduled by others
   - Involved in design implementation
   - Involved in goal-setting
   - Involved in decision making, arbitration
   - Involved in control system upgrading
   - Involved only in event of breakdowns or emergency

13. Who will be allowed to recommend/request changes or improvements?

   - Operators - maintenance technicians, engineers - supervisor - management

14. Are the prime objective/goals defined and documented?

   - Restricted access information
   - Openly published information
   - Abstracted, or detailed information

15. Are the acceptable methods of achieving the prime objectives/goals defined and documented?

   - As above plus priorities/preferences of methods

16. Are the constraints/restrictions for the achievement of objective/goals:

   - Temporary or permanent?
   - Legal or ethical?
   - Economic or technological?

17. What personnel-selection methods will be employed?

   - Internal upgrading/recycling
   - Screening and aptitude/skill tests
   - Competition or senority-rule

18. What personnel-training methods will be used?

- On-the-job training (timeshared or rotation)
- Buddy-system (with supervisor or senior operator)
- Published training manuals/aids/simulators
- On-line or off-line training
- Automatic upgrading by senority or ability
- Training by simulation machines or devices

19. Is there a program for turnover replacement?

- Scheduled or unscheduled (by time, by performance, or by potential abilities)

20. How is the performance of personnel evaluated?

- Measurable performance criteria
- Supervisor rated
- Continuous or periodic (what period/cycle?)

21. What is the organizational structure of the operating personnel?

- Team or task force (responsible to who?)
- Departmental

22. What are the operations-personnel reserve resources during crises or emergencies?

- Back-up force
- Re-assigned stand-ins

23. Will operator's successful operations algorithms be re-invested into automated control?

- As they occur
- With periodic re-design evaluations
- Or used instead to upgrade operator's training and operation requirements, and procedure manuals?

24. Is the facility or process a new one or a recycled (updated) one?

- Do precedents of performance exist? (for machine, for operators)

- Do stereotypes exist? (for machine, for operators)

25. How are conflicts resolved for operational methods?

- By on-line performance requirements
- By off-line management decisions (policies or laws)
- By decision maker(s)

26. Is the mode of operation based on desire to achieve previously unrealizable goal, or to maintain past history of success without failure?

The answers to these questions will establish the character of the personnel requirements which the MMIF design must satisfy!

Next, you should be able to answer:

for DISPLAYS:

What is being displayed? (Information item, validity)
Why is it being displayed? (Usage, causality)
How is it being displayed? (Physical form and location)
When is it being displayed? (Control of the display device timing)
Where does it come from? (From source directly or calculated)

But .... WHAT are you really telling the Operator?

for CONTROLS:

What is being controlled? (Device directly or calculated parameter)
Why is it being controlled? (Usage objective, algorithm)
How is it being controlled? (Physical form, strategy)
When is it being controlled? (Control of the control device timing)
Where does the control signal go? (Destination)

But .... what are you asking the Operator to ACCOMPLISH?

SUMMARY:

If each of the above checklist items can be confronted and described early in the system's design, we feel that the designer has a good chance to do a top-down design. The results will be early and powerful definition for:

- Data base description
- Signal and activator lists
- Statements of objectives
- Basis for project task breakdowns (allocations of effort)
- Early identification of R & D requirements
- Basis for strategy developments
- Potential problem areas.
- Algorithms of display and control

3.2 Human Factors Engineering

When it comes to the actual design specification, the characteristics of the human operator must be matched to the characteristics of available hardware, to meet system objectives. To achieve this, an understanding of the physical and mental performance limits of the operator should be taken into account.

This involves the relatively young field of scientific study called Human Factors Engineering (HFE). It is the scientific approach to the optimization of human perfor mance for performing physical and mental tasks. It is beyond the scope of these Guidelines to cover the extensive field of information that has accumulated on this subject. A vast literature exists. A very brief bibliography is included in the guideline which should provide the reader a useful introduction to Human Factors Engineering (HFE).

In brief, our interest here is to use HFE to attempt to provide quantitative and qualitative measures of man's sensory responses to stimuli as well as establishing his capacity for mental data-processing tasks. A popular approach to the study of the operator is to develop models. As an example, Fig. (3.2) depicts one such concept. No discussion of this model is attempted here. It is introduced merely to indicate the extent to which HFE attempts to study the behaviour of the human operator. The references must be consulted for a further understanding.

It would appear that the human data processing capability becomes the significant consideration in the design of the MMIF. It is not so much the physical aspects of the hardware that are of prime importance, but rather the encoding, organization and presentation format of data made available for decision-making purposes. The human must be able to absorb them, and make decisions, and take appropriate actions efficiently and accurately.

3.2.1 Decision Making

A checklist of questions that bear on decision making are:

1. How is it obvious that a decision must be made? - arousal and attention (alarming) -

2. What forms of perception are utilized for arousal?

3. What forms of action are used for resultant output?

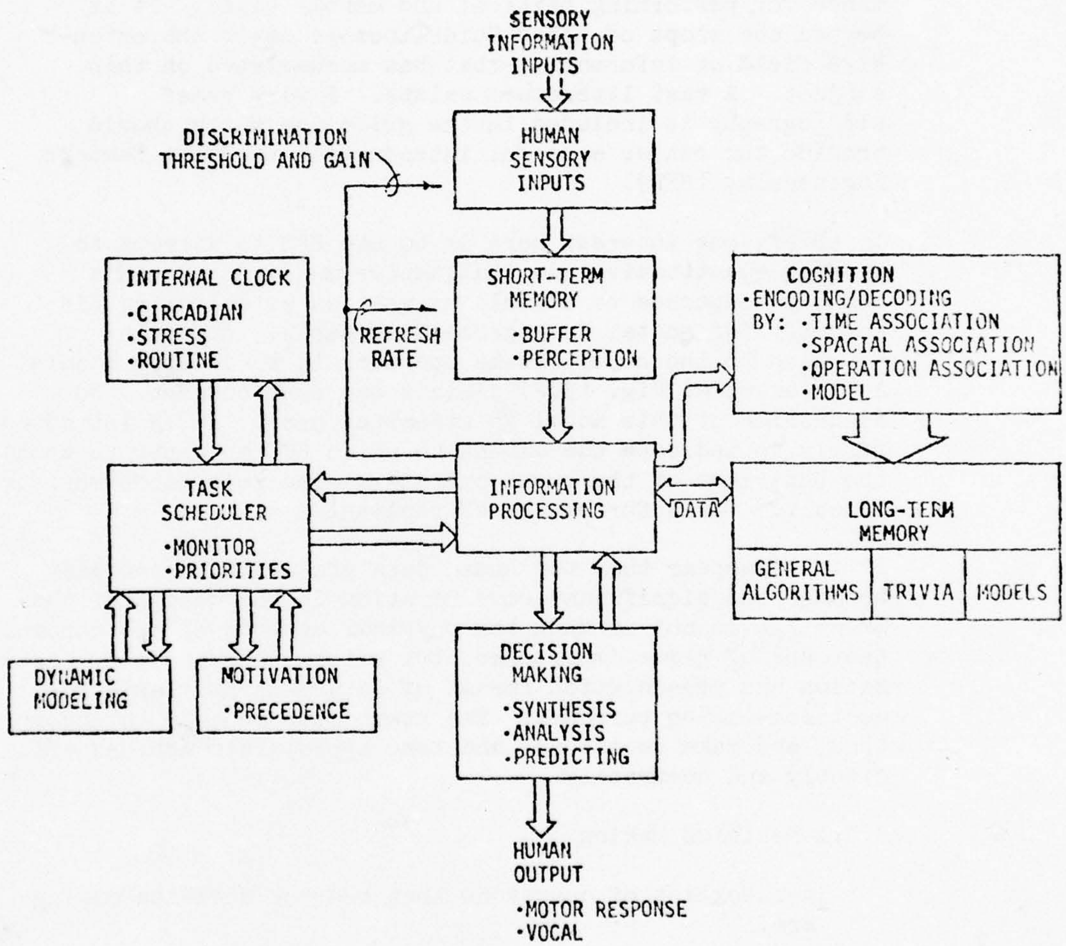


FIGURE 3.2

GENERAL INTERNAL OPERATOR MODEL

4. What are timing requirements on decision-making process?

5. What are accuracy requirements?

6. What is the information source?
   external process, actual data, real-time
   process model, simulated data, speeded-up
   model, predictive data, mental model

7. Are all relevant goals and objectives definable?

8. Are all allowable methods of arbitration/compromising outlined?
   speed vs. accuracy
   safety vs. economy
   efficiency vs. personal comfort

9. What are forms of input data?
   hierarchical, structured, filtered
   by demand, raw, noisy
   historical records/trending
   sampled data (time base)
   hysteresis, dead band limiting, and "wrap-around" effects

10. Are the real-time probabilities of values and excursions for input variables understood?

11. Are all probable errors accounted for?
   - substitution, reversal, ommission....

12. Does nature of decision involve qualitative or quantitative measures or data?
   differential (with or without ready reference?)
   absolute (on what scale?)

13. Are records available of previous/similar decisions and consequences?
   expectations (consistent or inconsistent
   process behavior)

14. Is feedback provided for consequences of present decision/action?
   - performance monitor (real-time, delayed, simulated)

15. Are operator conversions required between types of data as provided, and resultant control output required?

16. When is it obvious that a higher level of decision maker is needed?

17. Is the reliability or validity of the data (measurement devices) known or can it be checked?
    self-diagnostic instruments
    calibrated checks
    status or validation flags

18. Is it obvious when input information or output controls are faulty?
    behavior of status or validation flags

19. Are operator's display/controls compatible with the accuracy, speed, economy, and flexibility desired?
    economy: slow, serial, multipurpose devices
    accuracy: dedicated devices
    speed: paralleled-access devices
    flexibility: multi-assignment devices

20. Is quantitative information available in qualitative form when higher speed decisions are required?

21. Is the operational status of all data acquisition and control devices known? If not, can they be interrogated?
    verification of status or validation flags

3.2.2 Motivation

Motivation is a part of man's personality, but we are considering it seperately because of its importance in relation to his behavior as an operator.

Motivation can be considered to be made up of the following traits:

> Volition, curiosity, interest, initiative, imagination, knowledge, commitment, perseverance, drive, enthusiasm.

(Note: Human volition is what makes people create goals for themselves, and is the primary difference between biological systems and mechanical systems. Duty and obligation are forms of commitments. Curiosity and knowledge are prerequisite to the traits that follow in the list.)

3.2.3 Arousal

Arousal is the awakening or promting concept which attracts a man's attention so that he may begin processing information. In the case of perception,

each of the various senses has their own arousal threshold. In the case of man's internal information-processing, arousal provides cures which prompt further actions. The time between the first signal and the arousal is the arousal-lag-time.

We are concerned here with arousal as related to the external signals or cues which prompt an operator. These cues are called alarms if they are used for purposes of re-directing the operator's attention. In that event, they are really priority indications.

It will be useful to rank the level of arousals desired into some operational-related format as follows:

PRIORITY	CONDITION	COMMENTS
1st	CRITICAL	REPRESENTS A THREAT TO HUMAN SAFETY, AND NEEDS IMMEDIATE ATTENTION FOR CORRECTION
2nd	IMPORTANT	REPRESENTS A THREAT TO PHYSICAL PLANT INTEGRITY, AND NEEDS IMMEDIATE ATTENTION FOR CORRECTION
3rd	AUXILLIARY	REPRESENTS A THREAT TO THE EFFICIENCY OR OPTIMIZATION OF THE PROCESS, AND NEEDS ATTENTION
4th	AIDING	REPRESENTS HELPFUL OR SUPPLEMENTARY INFO., WHICH DOES NOT NEED TO BE ACKNOWLEDGED

Arousal Checklist Questions

1. Is alarm based on absolute, differential, or rate-of-change?

2. Are threshold detection limits fixed, variable, suppressable?

3. Are alarms structured for hierarchical consideration?

4. Are start-up and shut-down false alarming suppressed?

5. Is operator-prompting a part of the alarm system? (expectations)

6. Are alarm outputs on multipurpose devices or on dedicated displays and devices?

7. Is noise-filtering or statistical support provided? (validation)

8. Is pre-alarm recording available? (for DECISION-MAKING).

9. Is alarm system hardwired or automated? (computer)

10. Is there a back-up system? (for what other human senses?)

11. What is the average and instantaneous perception loading? (noise, glare, S/N ratio, environment....)

3.2.4 Response Time

Once the arousal threshold has been reached, and the operator is aware of a new input, information processing can proceed. The delay between the input condition sufficient for perception and a measurable output is defined as the operator's response time.

The actual value of response time is extremely dependent upon the type of encoding and accuracy required in any resultant, measurable output. The response-time flow is as shown:

$$\underbrace{\text{SIGNAL} \longrightarrow \text{PERCEPTION} \longrightarrow \text{AROUSAL}}_{\text{ARDUSAL LAG}} \longrightarrow \underbrace{\text{COGNITION}}_{\text{COGNITION LAG}} \longrightarrow \underbrace{\text{PROCESSING}}_{\text{PROCESSING TIME}} \longrightarrow \underbrace{\text{OUTPUT}}_{\text{OUTPUT LAG}} \rightarrow$$

Some of the recognizable cognition affectors are:

- Amount of extraneous information (noise)
- Strength, quality, uniqeness of information (errors)
- Motivation (commitment, duty, interest, pay-off)
- Physical and mental condition of man
- Type of perception involved
- Type of encoding (sequence, time, space)
- Previewed information (trending, modeling)
- Qualilative vs. quantitative input
- Skill, training, experience
- References and aids

Some of the recognigable processing-time affectors are:

- -priority-weighting and decision making, prioritity of task as related to priority of goals
- -experience and accuracy of memory models and algorithms
- -whether generalized algorithm, infrequently used; or specialized algorithm, frequency used
- -workload and stress
- -anticipation of event (look ahead technique)
- -accuracy of desired output (re-iteration and checking may be required)
- -consequences of errors (pay-off motivation?)
- -decision aids and back up information availability (for decoding-enhancement and redundancy)
- -type of processing (addition, multiplication are faster than subtraction, division; missing element detection, or exceptional-element detection, etc.)
- -validity of information or data items, or deduced probabilities of events

Some of the recognizable accuracy-affectors are:

- -time span of task, timing of feedback
- -speed requirements
- -motivation
- -references
- -feedback (speed and quality) for re-iteration
- -training, skill
- -physical and mental condition
- -resolution of output required compared to resolution of input data
- -methods of measurment, accuracy-verification-validity
  - -instrument
  - -supervisor
  - -model for comparison
  - -differential or absolute

3.2.5 Workloading

A man's workload can be defined as the measureable (real work) output plus his internal or mental workload. We are mainly concerned with his mental workload since his physical work output requirement is usually negligible.

Mental workload consists of all mental processing, whether it ever results in an output or not, and whether or not is was stimulated by a real or imaginary input or stressor.

Workloading can only be measured indirectly as related to a loss of thru-put, processing speed, and accuracy. Thru-put in turn can be defined as the relative measure of useful information-output of an operator, as related to the information-input required to produce it.

The most obvious and severe workloads on an operator are:

- unnecessary decoding and encoding (trivia)
- unnecessary perception-filtering due to excessive noise on inputs
- unnecessary output requirements (when machine-aiding is available)
- stress during upsets due to anticipated work and consequences of errors
- decision-making due to imperfect data (unknown validity)

By "unburdening" the operator, you can selectively:

1. reduce training time
2. reduce required skill or capacity level
3. reduce errors
4. increase safety
5. increase operator's reserve resources
6. increase consistency of behavior and operation

You can do this by:

1. making displays and controls compatible (transparency)
2. augmenting operator's less efficient talents
3. reducing trivia
4. data buffering, queueing, filtering
5. hierarchical alarming
6. aided statistical summaries/analysis/modeling
7. enhanced decision-making using information-validity flags

Or an operator will do it automatically by:

1. omission of his less critical tasks
2. allow errors to increase
3. allow efficiency to drop back
4. reduce resolution and discrimination
5. reduce responsiveness by increasing his control-lag and dead-band
6. changing mode of operation to releive his pressure
7. assumming validity states which favor easy decisions

Work-Loading Checklist Questions

1. What is the type of workload on the operator?
   - -anticipatory (threat of crisis)
   - -actual (physical, mental)
   - -stress (threat to personal life style)

2. Is operator's job designed around maximizing thru-put or maximizing reserve capacity for emergency?

3. Is operator's task to involve maintenance? Exercises and drills? Data Logging?

4. Are the social-interaction pressures identifiable?

5. What type of memory loading is involved?
   - -short term
   - -long term

6. What type of decision making is involved?
   - -amount of mental stress
   - -validity of information

7. What type of operation is involved:
   - -open loop, predictive, adaptive control, (pursuit)
   - -closed loop, (compensatory)
   - -operation by exception (monitoring)

8. What is the quality and quantity of data display? of control? of feedback?

9. What are the learning requirements on operator?

10. What are requirements on operator to furnish data inputs?
    - -amount, quality, type, method, timing
    - -consequences of default, error

11. Are consequences of work-load reduction most important because of man's comfort, performance requirements, or safety requirements?

12. What type of timing is involved? Man-pace-machine, or machine-pace-man?

3.2.6 Encoding/Decoding

All information presented to an operator is encoded in some form of spatial, temporal, sequential, or operational relationship. Likewise, all of the operator's output is encoded. It is of utmost importance to keep this encoding to a minimum, and

to have that minimum closely matched to the operational requirements of workload, accuracy, and response time.

The most straightforward encoding techniques are said to be "transparent", while more highly encoded information is said to be "noisy" and contain "trivia".

A "sterotype" is merely a realization of a specific encoding set of conventious and models of the real world environment as relating to objects, ideas, processes and so on. It is dependent upon regional populations, language, vocabulary, social status, education, etc.

It should be noted however, that a certain minimum amount of encoding and trivia is necessary to maintain some degree of realism and operator interest, and also to provide a certain uniqueness, or personality or "character", for seperate entities of the MMIF.

As an example of the use of encoding, consider alarming. In a parrallel-board array where all alarm indicators and interaction switches are present at all times, the operator has little need of a mental model, since he can relate the necessary response-algorithms directly to the spacial location of an alarm. He mentally stores his algorithm in the appropriate spatial-location of the alarm panel. If, however, the panel is large or only occassionally used, it will be helpful to provide secondary or "prompting" information.

Now consider when this alarm panel is automated and put on a CRT display, with computer-aided hierarchy. Now an alarm appears on a CRT, and the operator must read it, decode the language, and mentally match the message with the appropriate response. Response time is slower, and the workload is higher. If it were a "critical" level alarm, this would be a poor design. If it were a "helpful" level of message, no harm is done.

As another example for a CRT display or diagram, consider a valve-symbol or callout. The encoding of the symbol by shape, orintation, size, intensity, or color could indicate:

- is the valve open or closed?
- is it in manual, or local, or computer mode?
- is it in a faulty mode?
- is it in a state-of-maintenance?
- is it being by-passed for some reason?
- is it in standby?
- is the data or indication valid (confirmation required).

Where would further details be available if the valve symbol itself did not give its entire status?

- in a general purpose data base called by a general purpose program, keyed entry?
- by certain action on the valve symbol itself?
- on a bulletin board?
- on a supervisor's clip board?
- on a shift logbook?
- verbally from another operations person?
- by off-line communications to other personnel, must then visually inspect the valve for you?

Also consider for a CRT

- what happens when an operator enters an error?
- when he repeats an entry?
- when he omits an entry?

3.2.7 Job Aids

Job aids are of value not only to relieve the operator of heavy workloads, but also to improve his accuracy and response time. Aids can be provided to assist him with:

- time references (provide event indicators, trend charts)
- spatial references (provide models, graphic panels)
- operational sequence references (provide graphic panels,encoded prompting information.)
- short-term memory references (provide strong feedback and status information updated rapidly)
- long-term memory (provide bulletin boards, notes, indexes, drawings, pictures, reference manuals)
- decision making (provide historical and trending data, precendents, model situations, predictive or fast-modeling information.)
- information processing (provide scaling or calculating or normalizing information so that it is qualitative rather than quanitative)
- quantitative evaluations (provide time compression or expansion, differentiation, integration, spatial-compression or expansion, or useful rearrangement by intentional distortion, so that the operator can use comparison for evaluation).

In addition, the job aids could be manuals, procedures guidelines, policies, optimization data for the process as well as for operational modes, optimization goals, etc.

3.2.8 Training

Training is simply a collection of methods or procedures used to selectively increase specialized skills of a person. This is usually specified for a specific job requirement, and it is expected to be an efficient process. (Education, on the other hand, is defined as a more generalized program to increase reasoning, analysis and decision-making skills in a broader fashion; and is not expected to be an efficient or goal-directed process.)

The broad objectives of Training are to:
- increase skills (physical and mental)
- decrease errors (increase reliability)
- increase thruput (decrease response lag)
- enhance accuracy (resolution)
- increase motivation (self-confidence, duty)
- increase capacity (reserve)

The two obvious modes of training are:

1. ON-LINE

   On-line training is possible only when man is pacing or scheduling the machine, and errors are reversible and non-critical.

   The training-aids or job-aids could be:
   - Documents, manuals, charts,
   - Procedures, nomographs
   - Background-mode computer simulation

   The training-aids design will require:
   - Definitions
   - Requirements of system & performance criteria
   - Orientation infomation (models, diagrams, theory)
   - Procedures (operations-sequence, policy)
   - References and listings

2. OFF-LINE

   Off-line training is required when the machine paces the man, errors are irreversible and critical, and high resolution or accuracy is required.

   The training aids are likely to be:
   - Films, simulators, recordings,
   - Closed circuit TV, teaching machines

   The training aids design will require:
   - Process simulation or realism, including projected consequences of error, response time, accuracy, feedback information.

3.2.9 Psychological "Fit"

Here we are concerned with the psychological "fit" of the MMIF to the operator. All of the previously mentioned factors and categories come to bear in one final and composite "feeling" that the operator will have towards the machine.

Regardless of the success of the individual aspects of the MMIF, if this overall and <u>subjective</u> <u>"feeling"</u> of the operator toward the achine is negative, the project is doomed to failure -- or at the <u>least</u> doomed to the searching-out of an operator who will "fit"!

The purpose of the Guideline in this area is to make you aware of the aspects of this problem, the implications it can have on your project, and possible sources of further information on the subject (like the Bibliography).

An example will be given regarding the concept of "pacing" to illustrate the subtle effects of the psychological "fit" of the machine to the operator.

A man is said to be "paced" by the machine if he has <u>little choice</u> of what to do, and how to do it, and when to do it. He in effect is acting as a captive closed-loop-controller. On the other hand, man is said to be "pacing" the machine, if <u>he decides</u> on his own what to do, how to do it, and when to do it.

Man rarely if ever likes to be paced by a machine (the only obvious exceptions are competitive "games"). When he is, he can feel "threatened" or "crowded" by the machine, and this would be a bad psychological "fit". On the other hand, if the man felt he was pacing the machine, always understood it, and felt he was always in command, this would be a good psychological "fit".

Let's examine some aspects of the MMIF which affect pacing.

- During smooth operation of a plant running under management-by-exception, man is "pacing", generally.

- During emergency upsets, the machine could easily pace the man, unless the computer is used to support him by hierarchical alarming algorithms, automated recovery routines, operational guideline information, and so forth.

- During routine operations, if the machine is automated to the extent that a display tells the operator what to do, how to do it, and when to do it (like with a "programmed-text-book" approach and variably-assigned displays and controls, so that he is only given a selected, pre-defined set of data and controls) he could feel "paced". This could be avoided by "opening-up" the automated scheduler, so that the man could maintain freedom of the overall direction of the program, and escape or maneuver within it freely by his own choice.

- When entering a command to display or control a particular variable, the man could feel paced or "crowded" if he had to serially type-in a rather lengthy or complex string of characters in a rigid format, especially if the machine stops him instantly upon making a small error such as a software detectable syntax error, for example.

In summary then, the computer should augment the MMIF to such an extent that the operator is effectively releived of busywork or pacing activities, and is given the impression that he is in command of the machine at all times. He must never be "trapped" or "paced" by the machine; operators who are will tend to revert to their preferences of "traditional" wallborads of control; operators who have favorable experience under computer automation will actively participate in further automation activities.

3.3 Translator Functional Requirements

In these guidelines, the term "Translator" is used to represent the totality of hardware and software in the MMIF through which operators and process communicate with each other. Information and/or action flows through the MMIF from:

-translator to man

-man to translator

-1 Translator-to-Man Requirements

This subsection examines the functional requirements imposed on the translator by the operator's need for data presentation.

- Degree of Serialization of Data Presentation

  In the past, process control interfaces have characteristically provided the operator with all the information into and out of the system in a simul-

taneous, parallel, data presentation. As systems grew in complexity, it became obvious that the human mind had a finite data processing rate along with the realization that the operator may well be overlooking key inputs due to the overwhelming amount of data presented. Modern interfaces tend to reduce this mass of data into a more manageable form, by presenting the operator with only the data he requires soon for carrying out the specific task confronting him. This is termed a "serial operator interface", and the mode of selectively outputting preprocessed information is known as "management by exception". Management by exception implies that only off-normal data will be presented to the operator, thereby allowing him to concentrate his attention on current critical requirements of the system.

In designing such a system it is necessary to establish a hierarchy of data presentation to allow the operator to quickly access the actual loop or point to which he wishes to direct his attention. This may be accomplished by having the operator normally monitor a very macroscopic view of the process and then quickly and conveniently focus or "zoom-in" on the trouble spot. This technique efficiently overcomes the lack of simultaneous data display.

Such interfaces may still retain elements of parallel data display. For example, several CRT displays may be located on a console to allow the operator to keep a running summary of alarms always in view on one CRT, with a second CRT showing the trend of some group of troublesome points, and a third CRT used as a "utility" screen to call up those additional displays he needs for the ongoing monitoring and control of the process.

- Information Availability

Depending on the needs of the operator, the information may be made available by the translator in any of four modes:

- Continuous
- Periodic
- On-demand
- Automatic

The most critical functions may be required by the operator on a continuous basis and this implies dedicated presentation hardware.

Examples of periodic data requirements are found in hourly logs of all or groups of system parameters. This may well require a hard copy display for records of system performance.

On-demand presentation would form the basis for selective call-up of variables that are normally of low importance, and this method requires the minimum investment in display hardware due to the time-sharing possibilities.

Automatic presentation of data is one of the most important techniques, as it is implicitly required by the management-by-exception technique. In this mode the event is called up by the abnormality of the event itself. An example is a data-scanning system which outputs messages automatically when a point goes into alarm. As the quantity of data is not totally predictable as in the other modes, methods such as providing multiple CRT pages or hierarchical buffering must be used to handle a situation where many alarms can occur before the operator can process them.

- Flexibility

Flexibility refers to the capability of the translator to grow with the system and to provide a means by which the system attributes may be reconfigured. An example is found in systems permitting on-line modification of graphic CRT diagrams such as process schematics and pictorials. In these systems the operator or programmer calls up the format to be modified and types in the changes from his keyboard. When all modifications have been entered the operator pushes a button calling up a special program that stores his new diagram for future use. By these means the operator can rapidly alter his data presentation to keep it current with the state-of-the-process, and is an advantage unique to the CRT-based operation interfaces.

Another example of flexibility is found in translator designs that permit the data to be reconfigured into different combinations that are meaningful for the specific task at hand. For example, various process variables could be assigned to a CRT bar chart representing their current value or their setpoint deviation.

The more flexiblity built into the translator the greater will be its ability to adapt to future system needs. This must be balanced against increased translator design complexity, processing power, and programming requirements.

- Operator Aiding

  The most generalized requirement for a convenient interface design is to bring the data to the operator, not the operator to the data. The data should be arranged to minimize or eliminate the need to refer to look-up tables for interpretation of scaling, linerization, operating procedures, start up or shut down, etc. The alarm messages may present not only the time, date, point number, and nature of the alarm, but may also give the operator action-oriented instructions to guide him through the necessary corrective measures. Also, alarms may be classified as to degree of importance to help the operator quickly decide what action is most critical.

- Readability

  Operator acceptance of the control room equipment is tied strongly to the readability and display clarity of the display system. Included here we have considerations involving readability at normal viewing distances, absence of flicker, and proper control room ambient lighting.

  Display readability also involves proper differentiation of data classes through the use of color, character size and shape, and well organized groupings of data.

- Comprehension

  Operator comprehension of data benefits greatly from the management-by-exception principal, in which the only data presented is that needed by the operator at that moment. This technique effectively minimizes "sensory overload", which can occur in translator designs that output excessive amounts of data simultaneously.

Another key attribute for furthering comprehension is to arrange the presentation of information to be as intuitive as possible. Examples are in the use of trend recorders to graphically show process variations over a period of time rather than periodically printing out digital values of the variable. Also, CRT graphic diagrams can be configured to indicate a pictorial diagram of the plant or a section of the process, and show key real-time data for variables adjacent to the appropriate symbols of the variable. Thus the intuitive grasp of the system is increased by showing such variables as tank levels pictorically as well as digitally. (i.e. qualitatively as well as quantitatively.)

- Reliability

Translator reliability may be greatly improved by providing redundant information display capability at every operator location. For example, an operator may have two CRT displays at a console, and would normally use both. In the event of a failure of one, the other would furnish the most critically needed displays. In any event, no single failure should totally take down the MMIF station.

- Throughput

The throughput requirements of the translator are a function of:

- The amount of presentation hardware
- The frequency of presentation
- The presentation processing requirements
- The control room layout

For example, as the number of displays and display-update rates increase, the burden on the translator likewise increases. The type of displays used also impacts the translator processing requirement with, for example, CRT displays imposing a greater burden than in-line digital indicators. Also, various classes of CRT displays impose different throughput requirements on the translator, with random-scan displays normally needing more processing power than raster-scanning displays. The control room layout will also influence translator throughput if some of the work stations are so far removed from the translator processing equipment that relatively slow data transmission techniques must be employed to transfer the data. The throughput at these "remote" locations will be more difficlut to handle in that case.

3.3.2 Man-To-Translator Requirements

This subsection examines the functional requirements imposed on the translator by the need for operator interaction with the process through the translator.

- Degree of Interaction Required

  The sophistication of the system hardware and software required to provide operator interaction depends primarily on how often the operator must interact with the process through the MMIF. Sophistication is also highly dependent upon the criticality of that interaction and upon what stresses are imposed on the operator. Obviously the more often, the more critical, and the more stressful the situation, the greater will be the need for a translator design which permits rapid, accurate, and convenient control over the process.

- Classes of Interactive Hardware

  Interactive hardware may be either dedicated to a particular point or shared among many points. This ties in closely with the degree of serialization of translator hardware as covered in the preceeding subsection on translator-to-man requirements. Modern translator implementations tend toward more shared hardware with the exception of critical safety systems, which may be dedicated to a particular purpose.

- Degree of Serialization of Translator

  As mentioned under the translator-to-man subsection, modern operator interfaces tend toward a much greater degree of serialization of data display than in the past. This impacts on operator interaction because frequently the interaction will be accomplished via the same serialized data-presentation hardware. An example would be calling up graphical "pages" of displays on the CRT one at a time, to operate valves and breakers by direct interaction with symbols within each display.

- Requirements Imposed by Interactive Devices

  Speed - There is a wide range of speed at which available interactive devices operate. An example would be positioning the cursor on a CRT display via a keyboard equipped with keys that can move the

cursor up, down, right, or left one step at a time (slow); a trackball or joystick control which can move the cursor at variable rates along any vector (intermediate); and light pen control which can position the cursor randomly to any point on the screen (fast). The relative speeds of the devices mentioned have not considered the time it takes the operator to move his hand to that device, and that too must be considered!

Accuracy - Obviously the benefits of fast operation of an interactive device will be lost if the device does not operate accurately or consistently. This will be especially important during times of stress when such deficiencies are magnified. An example would be using a light pen that will not position the cursor accurately to the target area. To a certain extent the implementation of system design should compensate for the inherent limitations of interactive devices. (For example, providing the operator with a larger light pen target for important interactions).

Convenience - The same concepts of operator convenience as described under "readibility" must again be considered when designing MMIF interaction methods. This point is especially important with regard to operator acceptance of the system. The designer must take into account the requirements of accuracy and speed mentioned above, as well as good human engineering of the interactive hardware, by accounting for proper physical location of the devices as well as designing a high measure of "intuitive" operation into the required interactions.

Effects on display hardware - The requirement for interactive use will impose a higher level of sophistication on the display hardware by the required two-way flow of information. For example, CRT displays may require that the contents of the screen memory be capable of being read by the computer following for operator-initiated data and control inputs.

- Feedback

Every important interactive event the operator enters into should be confirmed with some form of feedback to signify that his action has been acknowledged. This can take the form of a color change on the CRT, a button lighting to say the computer is processing his entry, or simply an audible or

tactile feedback signal indicating acknowledgement that he has pushed the button. Indeed, it is usually important for the operator to be given feedback for each level of operation resulting from his input. For example, acknowledgement of:

- the proper functioning of the key (by a clicking sound)
- the computer acceptance of the request (by a character "typed" on the CRT)
- the program's acceptance of the "new datum" (by a color change or blink of the same character)
- the proper continuing operation of a program (by some form of "system heartbeat" display--for example, displaying digital clock time updated every second)

4.0 Implementation

This section discusses the means by which operators exchange information with the process through the MMIF by consideration of the methods of MMIF implementation. There are two functions evolved:

a) Presentation to the operator of information about the process and control system (alarms, measurement values, control mode, etc.);

b) Manipulation by the operator of information to convey his messages to the process (change a set point value, etc.).

4.1 Methodology

This section emphasizes a method of determining how to implement the functions of presentation and manipulation. It does not attempt to be a catalog of available devices, or a primer on their operation, or make specific recommendations for particular control schemes (set-point control, digital control), or of particular industry applications (petrochemical, power, etc.). The intent is to provide the designer of the MMIF with a methodology to enable him to select or specify devices to implement a functional solution, versus selecting a device first and then determining what can be done with it.

This method has three basic steps:

a) Task - identify the presentation or manipulation task (display a set point, change it);

b) Technique - determine alternate functional techniques which will accomplish the task;

c) Device - identify alternate physical devices which can implement the technique. Functional and physical capabilities of the devices must be considered to determine overall usability for particular applications.

- Personnel Requirements

For purposes of discussion in this section, anyone who uses the MMIF is considered to be the "operator", although in reality he could be some other type of personnel.

- Information Exchange Media

The media through which information is exchanged in conventional analog control systems are single-purpose instruments (controller, recorder, etc.) which are dedicated to particular loops by hard-wired connections.

The instrument's mechanical format determines the characteristics of the information exchange (content, amount, full-value, deviation, etc.).

In contrast to these conventional systems this section assumes that the primary information exchange medium is a computer-control system with a computer-driven interactive console which is shared among all loops. It is electronically formatted, under program control, to perform a variety of functions.

- Emphasis

Hence this section emphasizes the usability of "nontraditional" computer-driven devices, (such as CRT's, keyboards, etc.,) for "traditional" on-line interactive process control activities (like "change a set point", etc.). It should be recognized that the major advantage of these computer-driven devices, namely their ability to perform nearly any presentation or manipulation function through program design, is also the greatest pitfall to their usability. This is because programming must be viewed as the prominent tool to make the device reflect how "real" process-operators work, and not to reflect how programmers prefer to create interactive displays.

4.2 Presentation

In present day technology, visual and audible presentation-methods are the only techniques widely used. It is recognized that the other senses (touch, smell, taste, etc.) are employed, however, their application is very specialized and not a topic in this section.

- Visual

The presentation of visual data to the operator can be broken down as follows:

- Variables (i.e. setpoint, process)
- Scales (alarms, auto/manual)
- Tests (operator instructions, loop identification)
- Diagrams (flow, schematic, abstract models)
- Algorithms (formatting for displays, behavior for controls, configuration for control systems)

The following table lists the various presentation tasks, applicable techniques, applicable devices and comments.

TABLE 4.2

Presentation Task	Technique	Device(s)	Comments
Current absolute value of a variable or its deviation from a target	Pointer or Bar superimposed over scale	Analog Meter, plasma or LED array forming a bar, or similar display mimicked on a CRT	-Limited resolution even if the display is expanded or normalized. -Difficult to share display for a number of variables when scaled in engineering units unless CRT is used. -Good presentation of variable's relation to span (even when noisy). -Rate of change is somewhat discernible.
	Multi Digit	Dot matrix, seven segment, plasma panel, CRT electro-mechanical, etc. readouts.	-Resolution is limited only by the number of digits employed. -Easy to share for a number of variables. -Poor presentation of variable's relation to span (especially when noisy). -Rate of change is difficult to discern.
Trend or history of a variable	Graphical	Recorder or plotter	-"Rate-of-change" display is inherent. -Difficult to share for a number of variables. -Good resolution and bandwidth. -Inherent hard copy. -Extrapolation judgements may be made, allowing for "anticipation" of behavior.

TABLE 4.2 (Cont.)

Presentation Task	Technique	Device(s)	Comments
Trend or history of a variable (cont'd)	Line/graph	Recorder or plotter	-Troublesome paper handling and writing mechanism. -Record identification often has to be added.
		CRT	-"Rate-of-change" display is inherent -Easy to share for a number of variables. -Limited resolution with raster types -High resolution with random-vector types -No hard copy unless provided with additional hardware, i.e. video hard-copier, or camera, or auxilliary plotter -Records can be retained on computer memory devices, i.e. magnetic tape -Record identification can be provided easily
Relationship of the current value of a variable to a number of other variables	Line graph or bar graph	CRT or plasma panel	-Resolution dependent upon display type -Very flexible in format
		Multi pen recorder or plotter	-Good resolution -Limited format

TABLE 4.2 (Cont.)

Presentation Task	Technique	Device(s)	Comments
Mode of a loop	Illuminated Indicator or displayed mnemonic	Rear lighted push button, LED(s) rear projection displays, etc.	-Inconvenient if a large number of simultaneous states have to be displayed -Good interactive system if used with push-button
		CRT	-Can be tabulated for a large number of loops -Some potential for interactive system, i.e. cursor, light pen, etc.
		Page printer	-Can be tabulated for a large number of loops -Slow -Little potential for an interactive system -Often a complex mechanical device is involved
Alarms	Matrix display	Annunciators	-Hard to update for system changes -Poor potential for interactive system unless a matrix of illuminated push-buttons are used -Potential pattern-recognition -Space consuming -Lack of recording or "logging" abilities -Allow immediate, parallel access

TABLE 4.2 (Cont.)

Presentation Task	Technique	Device(s)	Comments
Alarms (cont'd)	Matrix display	Dedicated CRT	-Software updatable -Potential for interactive system, i.e. light pen, etc. -Compact -Potential pattern-recognition capabilities -Lacks recording or "logging" abilities unless auxilliary equipment provided.
	Tabular display in chronological, hierarchical, or arbitrary order	Assignable CRT	-Software updateable -Potential for interactive system, *i.e. light pen* -Lacks recording or "logging" abilities unless auxilliary equipment provided -Compact when serialized, but then requies serial-accessing techniques (hierarchy) -Ability to arrange in order of importance -Little potential for pattern recognition -Ability to add operational guidelines or notes
		Page Printer	-Software updateable -Little potential for pattern recognition -Noisy -Inherent recording or "logging"

TABLE 4.2 (Cont.)

Presentation Task	Technique	Device(s)	Comments
Text	Illuminated dot(s) in an array	Plasma array (usually a 5 x 7 dot array per symbol)	-Flat faced -Requires little depth -Requires no refresh memory in computer -Flicker free -High-contrast, bright -Only one color (orange or green) -Inflexible format -Relatively high cost-per-character -Easy software interface

TABLE 4.2 (Cont.)

Presentation Task	Technique	Device(s)	Comments
Text (cont'd)	Illuminated dot(s) in an array	CRT employing raster scan, 30Hz, interlaced fields	-Horizontal single element lines may flicker -30K picture "elements" possible -Easily remotable -Many colors possible -Relatively inflexible format -Relatively inexpensive -Easy software interface -Intermediate brightness, contrast -Low maintenance
		CRT employing raster scan, 60Hz, non-interlaced fields	-Flicker free -Relatively flexible format -156K picture "elements" possible -Requires "specialized" TV raster format -Many colors possible -Relatively easy software interface -Relatively inexpensive -Remotable -Intermediate brightness, contrast -Low maintenance
	Illuminated line segments	CRT using D.C. beam positioning	-Characters are "stroked" for potential improvements in readibility and resolution -High brightness, contrast, resolution -Unlimited and flexible format -Relatively expensive -Difficult software interface unless auxilliary controllers provided -Limited colors possible (red, orange, yellow, green) -Intermediate maintenance -Non-remotable -Difficult to provide hard copy

TABLE 4.2 (Cont.)

Presentation Task	Technique	Device(s)	Comments
Diagrams	Illuminated dot(s) in an array	Plasma array	-Flat faced, allows rear-screen projection -Inflexible Format -One color (orange or green) -Easy Software interface -Requires little depth -Requires specialized hardcopiers -Requires no refresh memory -Not directly remotable -Flicker free -Intermediate expense -Low maintenance
		CRT employing raster scan, 30 Hz, interlaced-fields	-Horizontal single element lines may flicker -Easily remotable -Possibility of multiple colors -Hardcopiers readily available (without color) -Limited graphic capability when the display is made up of an array of individual symbols -Inexpensive display monitors -Intermediate difficutly in software interface -Intermediate graphic capability when the display is made up of addressable dots (65k dots at 30Hz or 262k dots at 60Hz, usually)
	Illuminated line segments	CRT employing D.C. beam positioning	-Ideal for graphics -Unlimited formats -Expensive -High resolution (1M dots) -Limited colors possible (red,orange,yellow, green) -High brightness, contrast -Difficult Software interface unless auxilliary controller provided -Non-remotable -Difficult interface required for hard copy

- Audible

The use of audibles in conventional systems is usually designed to interrupt the operator's activity and either envoke pre-determined action, e.g. shutdown, clear area, etc. or direct him to another source of information, e.g. look at annunciator, read teletypewriter, etc.

Through the use of audibles having different characteristics, different message can be conveyed. The basic drawback, however, is the psychological limitation in the amount of information conveyable. The advantage in the use of audibles is that the operator's hearing function is usually unencumbered and a significant sound will interrupt him regardless of his activity.

Conventional audibles are in the form of:

Harris Horns
Bells
Klaxons
Sirens
Whistles
Solid state such as piezo electric devices

- Voice Response

Emerging in present technology are devices which will generate human speech. Such a device obviously opens up a whole new communication channel to the operators without the limitations of the previously described devices. One such device converts the output of a computer into simulated human speech. This conversion from digital information to simulated speech is accomplished thru design which divides each human word into phonemes, such as vowels or consonants. For example, the word "hello" consists of the phonemes "H", "EH", "L", "UH" and "O". Each phoneme is represented by a digital word. These phonetic command words are converted into the corresponding phonetic sounds and define the inflection level or loudness of the phoneme.

4.3 Manipulation

Manipulative devices are the physical means by which the process operator transmits his commands to the control system and process. Hence they are the first stage of translation from "man language" to "machine language." The goal in designing the manipulative section of the MMIF should be to avoid imposing unnatural machine-language constraints on this initial stage. Manipulative actions should reflect "plain English"[1] and traditional (stereotyped) process-dependent terminology. This section discusses program-controlled manipulative devices which interact with electronically-

[1]...or whatever is the native language being used!

formatted display devices which comprise the display medium for all information used in primary on-line control operations (set point, measurement, output values, control status, alarm, trend, process graphics, logs, etc.).

These devices are:

- -Fixed-function keyboards
- -Variable-function keyboards
- -Light pens
- -Touch screens
- -Speech recognition

(note: the terms "keys" and "buttons" are used interchangeably)

This section does not cover hard-wired devices dedicated to particular functions (motor-starter pushbuttons, etc.), or directly associated with ancillary MMIF equipment (recorder patch panels), or captive controls (recorder chart drive selector switch, hand copier on/off switch etc.).

- Human Manipulative Senses

The human motor-response (hand-controls) and vocal output response are highly developed for directly interactive control tasks (changing controller mode, value, etc.) but are commonly overloaded.

Human vocal output has been used mostly to supplement hand controls for indirect tasks (relaying information via radio-telephone). Recent advances in computerized speech technology are promising, but their application to directly interactive control-tasks is unclear. Hand-operated tactile devices are dominant. Those suitable for interaction with computer-driven displays are light pens, touch screens, and various types of keyboards. Foot-operated tactile controls are common in aerospace, machine-tool and vehicular applications, but are not as frequently or as effectively used in the primary process industries as they perhaps could be.

- Devices Descriptions

Manipulative devices are classified as variable-function or fixed-function, as follows:

Figure 4.3 Manipulative Device Classification

Device	Human Output Category	Functional Category
Fixed function key		Fixed
Variable function key Light pen Touch screen	Motor response (Hand-operated)	Variable
Speech recognition	Voice	

- Fixed-Function Key

A key which has a single dedicated function, identified by a label affixed on or adjacent to the key top. There are two general types of fixed-function keyboards:

1. Universal format (USASCII, etc.)

2. Custom format

- Variable-Function Key

A key whose function is not fixed, but varies according to display conditions, previous action of another key, etc.

Variable-function key boards utilize a common arrangement of blank (unlabelled) keys which are labelled in several ways:

-CRT - keys are aligned with locations on CRT (usually under or alongside screen) and CRT labels are displayed under program control

-Overlays - sheets on which labels are printed or handwritten, and positioned by hand to be adjacent to or over keys (with or without cutouts for keys)

-Shifting - shift or "mode" keys are used to change among a fixed set of alternate functions, labeled on or adjacent to keys (examples: Teletype, keypunch, numerous hand-calculators)

-CRT labelling - the most flexible and powerful. The number of labels is unlimited. Operating procedures can be completely self-explanatory (akin to programmed textbooks) wherein current labels follow from previous actions. "Illegal actions" can be eliminated by displaying only labels pertinent to current display conditions (type of loop addressed, its set point status, etc.).

Similar techniques can be used with light pens and touch screens, and are equally flexible and powerful.

- Light Pen

A light pen is a hand-held "active stylus" which addresses a position in a CRT display by pointing at it. This identifies the corresponding CRT beam x-y coordinates in the matrix of possible CRT beam positions, which is then decoded to determine the addressed function.

The light pen is an "active" device since it contains an electro-optical switch which responds to the display's phosphor luminescence. A wire carries the signal from light pen to decoding circuitry. The CRT beam position matrix is "passive" since it exists only as a list of addresses in computer memory. Appropriate software must be provided to allow "activation" linkages corresponding to screen coordinates being pointed at by light pen.

- Touch Screen

A touch screen is essentially the inverse of a light pen. It uses a "passive stylus" (finger, pencil, etc.) for pointing at the desired display position. The pointing actuates one electronically sensitive area in an "active matrix" which is deployed over the display. This is decoded to determine the addressed function in a manner similar to the use of the light pen.

The switch matrix can be created in several ways:

-Mechanically - crossed (x-y) wires between transparent plastic sheets, laid directly over the display surface; actuated by pushing wires together

-Optically - visible or infrared light transmitters/ receivers are located around the display surface in a "picture frame"; actuated by interrupting the light beam

-Acoustically - similar to optical but uses sound transmitters/receivers; actuated by an acoustically-active pen.

-Electronically - distributed electrical properties of screen are precisely balanced by electronic sensing circuitry; activated by touching screen, upsetting balance.

In any event, it should be noted that touch screens can be used with any display medium; they are not a CRT-dependent device. Common resolution capabilities are to the inch or CM, but resolutions to a few thousandths of an inch are available.

- Voice Recognition

Computerized techniques are becoming available which can recognize spoken multisyllabic words and phrases with good accuracy. However, numerous restrictions exist on vocabulary, training of machine and man, etc. This technique has been used mostly in nonprocess control environments where the motor response outputs are overloaded (both hands full loading packages, with requirement to describe package to a central data processing system), or not available (control inputs being made over a voice-communications channel).

Voice recognition could be useful in process control situations to supplement traditional techniques, and would constitute an improvement in tasks such as loop addressing (it should be easier to say "display FRC100" than to type in at least six alphanumeric characters or find the fixed-function key dedicated to that loop). Its usefulness as a general purpose or primary manipulative technique for all actions is unclear (it is more compact to manipulate a "ramp" button to adjust a value than to say "ramp the set point value to XXX.X at a rate of Y", and then interrupt the ramp if needed). Also, verification of voice command interpretation would be needed prior to exectuion of the command, and editing and cancellation methods would have to be developed.

- Evaluation Factors

Devices must be evaluated as a <u>medium</u> for implementing a <u>technique</u> for accomplishing a manipulative <u>task</u>. Hardware design should follow naturally from functional design.

The evaluation process has an objective/quantitative side (which devices can do the job functionally and physically?) and a subjective/ qualitative side (which fit best into the overall operating procedure philosophy?).

A good example is the question of whether to choose an optimum device for each task, or to use the same device for all tasks?

> On the objective/quantitative side, human factors testing can demonstrate that human performance is clearly superior for a certain task with a certain device (in terms of accuracy, speed, repeatability, fatigue, natural hand/eye coordination, etc.).
>
> On the subjective/qualitative side, however, there are strong arguments for the consistency of operation (hence safety, ease of training, etc.) obtained by using the same device for all tasks. It is also important to consider how the device affects (or is affected by) overall work station characteristics (size, shape, standup/ sitdown, etc.).

Thus the most important attribute to a useful overall solution is that it be logical (sensible) and natural (easily learned and retained) for the operator. This is usually a better solution than a collection of individually optimum solutions.

The most obvious compromises in performance between choosing a fixed or dedicated-function device and a variably-assigned-function device are as follows:

- Dedicated function--Once the operator is trained, he can exhibit a very short reaction time in the use of the device, and the error rates are generally very low. The operator's short term memory is very lightly loaded because the devices are self-identified according to their function, and thus very little or no encoding is required. The disadvantage lies in the inflexibility to change, and the tendency of dedicated devices to proliferate and require extensive layout space. A certain point can be reached where they cover such a large space that the operator's reaction time is <u>degraded</u> because of search time and long-term memory load! Errors would then also increase. However, this method is recommended for "critical controls" because of the likelyhood of short-term memory overload during emergencies, but especially because of the need for quick response.

-Variably assigned - Once the operator is trained, and after the automated assignment algorithms are optimized, the reaction time and error rates can be better than with dedicated devices. In this case, the operator's short-term memory is required to process the sequential meanings of the assignments, but his long term memory is effectively releived by the automated assignment routines. Therein lies the difficulty, however, in the critical need for thorough software design and evaluation. Once that is handled properly however, this method exhibits superior flexibility, and compactness. One must be careful to allow appropriate sequential controls or escape-mechanisms into the algorithms, so that the operator doesn't get "trapped". Also, this method might not be appropriate for "critical" controls.

4.4 Task/Technique Characterization

The first two steps toward realizing these attributes are:

1. Thorough understanding of the operator's manipulative tasks in terms of the type of manipulative action involved and its human performance characteristics;

2. Recognition that alternate techniques usually exist for accomplishing each task, and alternate device for implementing each technique.

This will go a long way toward assuring that a single technique/device solution is not "unnaturally" or "illogically" imposed upon all task problems. Figure 4.4.1 illustrates these two points for the example information organization of Figure 4.4.2.

Task	Technique	Characteristics	Alternate Techniques
Display manipulation	Address	General: non-critical (does not affect process conditions)	Identify position in display (cursor; stylus; row-column)
	-Area/Group/Loop		
	-Loop variables	-Selection from fixed alternates in fixed position in display	-Explicitly identify name (compose by typing; voice)
	Control (Set, Out, Ratio, Bias)		
	Alarm (Hi, Lo, Dev, Deadband)	-Visual search to locate on display	-Single named key
	Tune (Prop, Reset, Deriv)	-Visual verification	
	-Call supplementary displays for selected Area/Group/Loop	-Selection from fixed alternates	-Explicitly identified display
		-Visual verification	-Name (as above)
Process/ control manipulation	Change loop status:	-General: critical (affects process conditions)	-Explicitly identified status name (as above)
	-Service (in/out of service)		
	-Control variable (Set - L/R, Out-A/(M)	-Selection among 2 or 3 fixed alternates	-Single named key
			-Named positions on selector switch
	-Alarm (enable/disable)	-Visual verification	
	Change value:	-Gross or vernier changes within fixed ranges	-Complete new value (numeric data entry; ramp)
	-Control variable (Set, Out, Ratio, Bias)	-Visual feedback (analog pointer against scale; digital readout)	-Increment of change (numeric data entry; ramp)
	-Alarm (Hi, Lo, Dev, Deadband)		
	-Tune (Prop, Reset, Deriv)		
	Acknowledge alarm;	-One step change from current conditions	-Single named key

FIGURE 4.4.1

TASK/TECHNIQUE CHARACTERISTICS

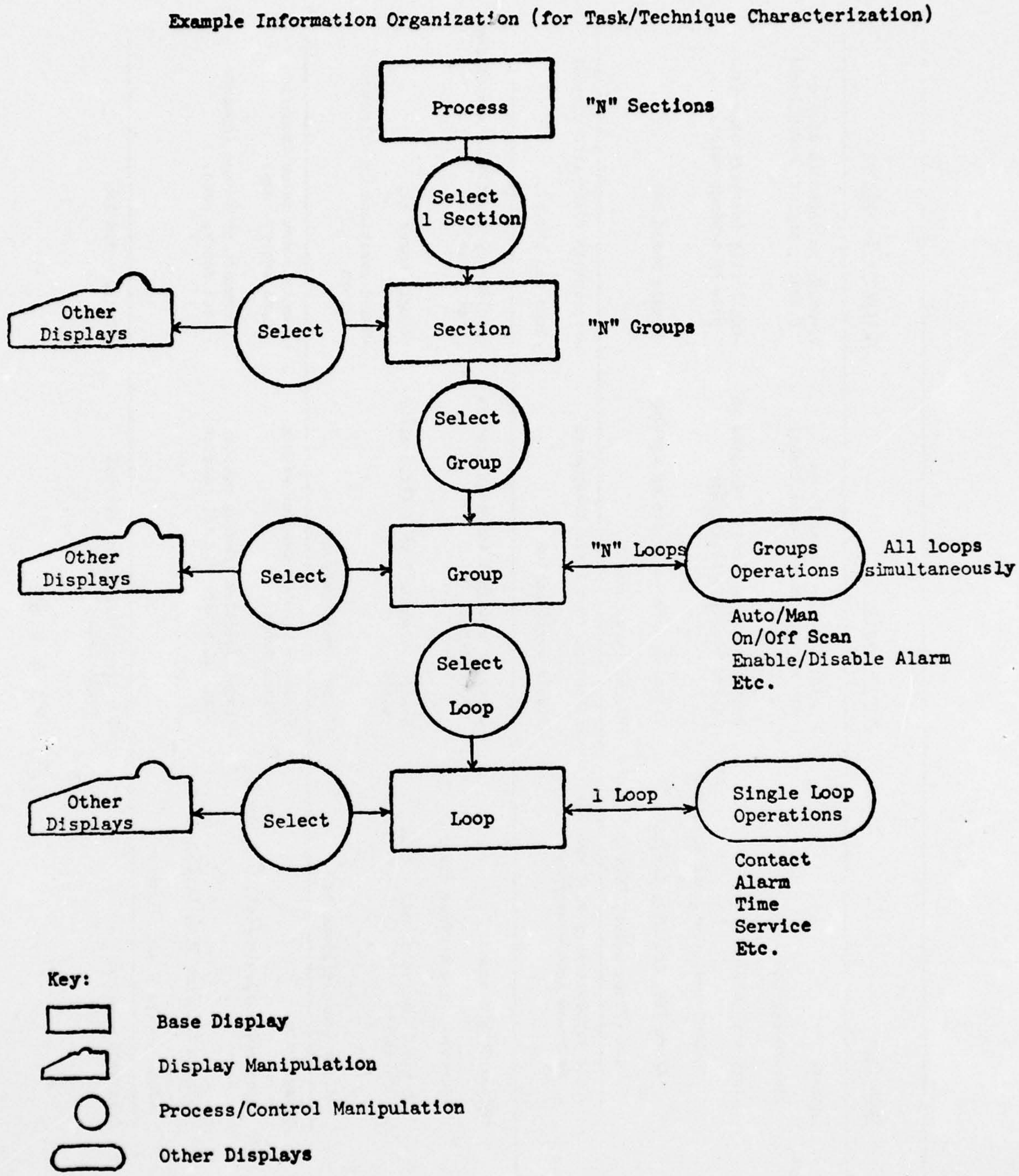


FIGURE 4.4.2

EXAMPLE INFORMATION ORGANIZATION
(for Task/Technique Characteristics)

4.5 Device Usage Characteristics

The next step after identifying task/technique characteristics is to identify alternate devices which can functionally implement the desired technique.

All the devices covered by this section can be functionally interchangeable. But each has distinguishing characteristics which cover the gamut of human factors, physical, programming support, cost, etc. These are summarized in Figures 4.5.1 through 4.5.

The evaluation factors above can now be applied toward final device selections.

Device	Use	Operating Principles	Usage Characteristics
FIXED FUNCTION KEYBOARD	Push any key	1. Each key dedicated to single, unchangeable function	1. General
	1. Move arm/hand to keyboard from rest position	2. Operator selects according to memorized operating procedure	.1 Large number of keys - can approach one per function; usually requires grouping - hard to group efficiently for all operating procedures
	2A. Position finger to key(s)		.2 Require frequent gross arm/hand movements for searching
	2B. Push/release key(s)		.3 Action area typically 15" x 5" minimum
	3. Return arm/hand to rest position		
			.4 Same function always performed on same key
			.5 Changes difficult since involve hardware
			.6 Least programming required
			2. Universal format (USASCII)
			.1 "Incremental-function" keys (single alphanumeric character)
			.2 Operating procedure by sequential text-entry (type-in multi-character function names). Touch-typing possible.
			.3 Difficult to make keys a single-complete-function without awkward coding
			3. Custom format
			.1 Keys can be "single-complete-function" or "incremental"; tradeoff among number of keys, complexity of decoding logic, etc.

FIGURE 4.5.1

FIXED-FUNCTION KEYBOARD CHARACTERISTICS

Device	Use	Operating Principles	Usage Characteristics
VARIABLE FUNCTION KEYBOARD	Push labelled keys 1. Move arm/hand from rest position to keyboard 2A. Position finger to key 2B. Push/release key 3. Return arm/hand to rest position	1. General .1 Standard arrangement of blank (physically unlabelled) keys .2 Labels varied by: .1 CRT - by program per current display conditions, previous key action, etc. .2 Overlay - manually positioned; active keys can be lighted; fixed labels per overlay sheet .3 Shift keys - shift among fixed alternates per key (usually 2 to 4) .3 Keys can be "single complete function" or "incremental function" 2. CRT labelling .1 Only labelled keys active; other inactive; no "illegal actions" .2 Operating procedure like programmed textbook (leads you through)	1. General .1 Fewer keys than fixed-function-keyboard (1:5 minimum for CRT labelling vs. USASCII keyboard, up to 1:1000 for CRT labelling vs. fixed assignment; less arm/hand movement, searching, etc. .2 No effect on display design since no symbology required, for "active areas" for light pen/touch screen .3 Comfortable rest and action positions for arm/hand/fingers for all actions 2. CRT labelling .1 Keys, key labels, primary display information in same visual field; effieicnt hand/eye coordination; minimizes searching; immediately adjacent to display .2 Little arm/hand movement since few keys active at any time (as few as 10); labels can be concentrated in one area of keyboard .3 Action area (15" CRT) = 1 character line = 12" linear .4 Same label (and function) may appear on different keys at different times .5 Labels naturally grouped for all operating procedures .6 All changes by programming

FIGURE 4.5.2

VARIABLE FUNCTION KEYBOARD CHARACTERISTICS

Device	Use	Operating Principles	Usage characteristics
LIGHT PEN	Point at display 1. Move hand from rest position to LP stowage location 2. Unstow LP 3. Move arm/hand/LP to display 4A. Position LP precisely 4B. Actuate 5. Remove from display/restow LP 6. Return hand to rest position	1. Active stylus (electro-optical switch) moved in passive matrix of CRT beam positions (list of addresses in computer memory) 2. Switch closure interrupts light from illuminated phosphor into LP, thus indicating current CRT beam position to decode logic 3. Decode logic interprets CRT beam position against cross-reference of functions	1. Wire from LP to decode logic is encumbrance 2. Use usually requires more arm/hand operations than KB (see "Use" column) 3. Frequent gross arm/hand movements for positioning 4. Arm/hand position fatiguing for sustained actions 5. Requires accurate placement perpendicular to display, line-of-sight 6. Indefinite target (no physical guidance like KB) can impair speed, accuracy 7. Arm/hand/LP blocks view of display adjacent to active area 8. Resolution can be 1 CRT beam position increment (giving about 65K "active" locations) 9. Display labeling more flexible than for physical KB. 10. Display must symbolically indicate active areas 11. Physically fragile 12. Optical receiving surface must be clean 13. Direct hand/eye coordination since functions in same visual field as display; can be exactly at same location as display feedback 14. Programming support similar to Touch, Variable-Function-Keyboard 15. Works best with bare CRT faceplate (no contrast filter)

FIGURE 4.5.3

LIGHT PEN CHARACTERISTICS

Device	Use	Operating Principles	Usage characteristics
TOUCH SCREEN	Point finger at display 1. Move arm/hand from rest position; deploy finger 2. Point finger precisely 3. Remove finger 4. Return arm/hand to rest position	1. Passive stylus (finger, pencil) moved in active matrix (electrical switches) imposed over display surface 2. Switch closure identifies x-y location of touched display element to decode logic 3. Decode logic interprets against cross-reference of functions 4. Switch mechanisms .1 Crossed wires - fine wires between transparent plastic sheets in x-y arrangement; push at intersection .2 Optical - interrupt light waves projected across display surface .3 Sonic - similar with ultrasonic waves .4 Electrical - "sensitized" areas on faceplate sense capacitance or resistance changes .5 Acoustic-sensors along display edges detect acoustically active pen location	1. Use usually requires more arm/hand movements than for KB 2. Fingerprints on display surface are an annoyance display viewing 3. Targets are distinctly outlined by CRT labels 4. Resolution density limited by finger size (about 3/4" grid, or 12X16 matrix on a 9"X12" CRT, giving 196 locations) 5. Can be used with filtered CRT's 6. Optical and sonic types rugged 7. Only "active" and "legal" functions shown 8. Can be used as dedicated functions, grouped and serially-batched functions, or dynamically-variable functions 9. Large martrix size allows pattern-recognition arrangements, and fixed locations, simultaneously 10. Fastest reaction time (pressing finger on displayed item of interest) 11. Can provide color coding by using color CRT 12. Display labelling more flexible than for physical keys 13. Less short-term memory load than for variable keyboard, since control is implicit to display rather than associative

FIGURE 4.5.4

TOUCH SCREEN CHARACTERISTICS

Device	Use	Operating Principles	Usage Characteristics
VOICE RECOGNITION	Speak commands into microphone	1. Computer program recognizes human speech and interprets against function library	1. Present state-of-the-art requires trained operators, specific vocabularies, paced speech, etc. 2. Can be used in combination with other manipulative techniques for redundancy 3. Can recognize multi-syllabic words, phrases (word strings) 4. Requires structured speech, coded words, etc., for equal operational efficiency with single-complete-function keys 5. Very expensive 6. Developmental techniques required 7. Extremely flexible and potentially powerful 8. Allows human input almost independent of motor-response workload 9. Almost no short-term memory load, long-term memory load comparable to other techniques.

FIGURE 4.5.5

VOICE RECOGNITION CHARACTERISTICS

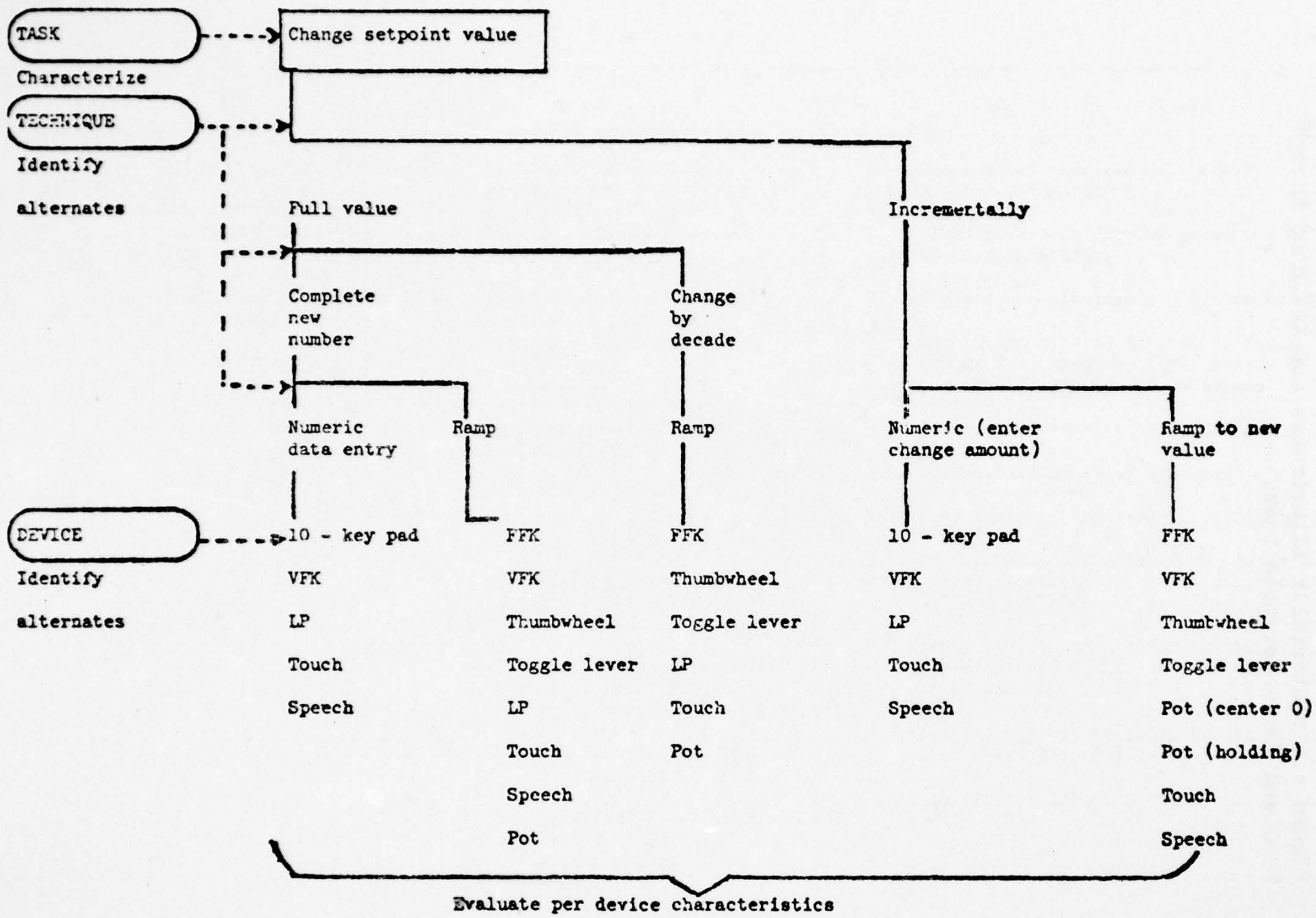


FIGURE 4.6
EXAMPLE EDUCATION TREE
(Illustrating This Method)

AD-A036 457 PURDUE UNIV LAFAYETTE IND PURDUE LAB FOR APPLIED IND--ETC F/G 9/2
SIGNIFICANT ACCOMPLISHMENTS AND DOCUMENTATION OF THE INTERNATIO--ETC(U)
JAN 77 N00014-76-C-0732

UNCLASSIFIED NL

2 OF 2
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A036457

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DATE
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3-77

4.6 Example Evaluation Tree

The philosophy of this method has now been described and its component parts identified for selecting manipulative devices. Figure 4.6 pictorially illustrates the train of thought involved for an example task.

5.0 Glossary

Aesthetics - A "quality" concept, relating the conformance of an item to some preconceived notion or stereotype of the same item. If this relationship is favorable, the item "fits in", and is said to be aesthetically pleasing. If this relation ship is disfavorable, the item fails to fit, and is said to be aesthetically displeasing.

Annunciator - Self-contained devices used to indicate, but not record, alarm conditions.

Arousal Threshold - The level of an input and/or the time it must be asserted before recognition occurs by the operator.

Bulletin Board Effect - The tendency in man/machine control centers of using all available unused panel space (and writing surfaces) for offline information. (ie. operator notes and messages)

Clock Shop - The appearance of a control room where all of the walls and panels are covered with meters, dials and knobs.

Cognition - Preception-related recall from long-term memory.

Compatability - The appropriateness of a display to a control; also of a display or a control to a task, especially related to the correllation of cause and effect. True compatability implies less need for translation by the operator.

Console - The machine side of a man/machine interface (alternate definition).

Control Room - Any center of activity for a manned system, but specifically one which contains a man/machine interface.

Display - A visual information transmission device which is driven by some form of instrumentation (alternate definition).

Glyph - Figure or symbol used as an abstraction of some physical reality or event.

Iconic Communication - Communication presentation by visual imagry, especially those which move and change with time.

Job - A set of tasks assigned to some person (alternate definition).

Key Operator - A person trained and responsible for a given operation.

Man/Machine Interface - The interface between man and machine, where man's output is translated into machine input and vice versa.

Man/Machine System - A system in which a man is a component and a contributing factor to the system performance (the manned portion of a system could be a considered sub-system).

Noise - Any input to a system that does not contribute to the usable output of the system. (Alternate definition).

Off-Line - Matters indirectly related to machine, such as documentation. (Alternate definition).

On-Line - Matters directly related to machine in "real-time". (Can be man-to-man communication). (Alternate definition).

Preception - Sensory information gained through the use of short-term memory.

Population Sterotypes - Tradition, convention, or commonly expected behavior or characteristics. Associated with a particular population group (for example; reading from left to right, top to bottom; right handed threads, etc.).

Sign - A sign is any information display which is not connnected to instrumentation and is never interactive with respect to feed-back and control. (Alternate definition).

Task- An operation to be accomplished within a system by either man or machine. (Alternate definition).

Task Analysis - Analyzing or dissecting what is functionally being accomplished, and classifying its component parts.

Task Description - Complete item-by-item specification of the individual tasks, which taken together, comprise the total job activity of the operator.

Task Synthesis - Assembling the individually specified components of a function in order to comprise his whole.

Top Down - Abstracted analysis of what is to be accomplished, without arbitrary constraint, but rather guided by requirements of the ultimate end-result or goal. This approach requies the definition of the system and its attendant problems before approaching the methods of solution.

Trending Recorder - A data recording of the immediate past behavior of a process. Used to extrapolate the behavior of the process in the immediate future.

Trivia - Apparently arbitrary representations or translations of real world events; anything which masks or occludes valid information.

Transparent - That which is intuitively obvious or straight forward, requiring little or no translation.

5.1 SUPPLEMENTARY GLOSSARY

The following list of terms are used in the general area of the design of man/machine interfaces and have already been defined by the industrial digital computer terminology dictionary prepared by the glossary committee of Purdue workshop on standardization of industrial computer languages.

Alarm	Analog	Backup
Channel	Communication	Computer Console
Console	Control	Control System
Conversational Mode	CRT Display	Data
Digital	Display	Emmulate
Event	Graphic	Hard Copy
Hierarchy	Information	Interface
Interlock	Joy Stick	Loop
Manual Operation	Mode	Noise
Off-Line	On-Line	Operator
Optimize	Plot	Process
Rank	Record	Reliability
Remote Stations	Selection	System
Task		

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